APPENDIX B

APPENDIX B.1. PRELIMINARY PHYTOPLANKTON STUDY

(G.C. Grant and S.P. Berkowitz,
Virginia Institute of Marine Science)

B.1.1 Objective

Preliminary study to characterize the summer phytoplankton community in the study area and to determine the effect of plant operations on local phytoplankton populations.

B.1.2 Data Source

Ref. 10.

B.1.3 Study History

July-September 1978.

B.1.4 Study Methods

- The waters around the plant were divided into four subareas: A-Seneca Creek (intake); B-Upper Saltpeter Creek (discharge); C-Lower Saltpeter Creek; D-Gunpowder River. Four samples were collected monthly in each of the four subareas. Sampling stations are indicated in Figure B.1-1.
- Ancillary measurements taken at each sampling station included: water temperature, conductivity (salinity), dissolved oxygen, alkalinity, subsurface light penetration (secchi disc and submarine photometer), seston (gravimetric), and surface incident radiation.
- Chlorophyll a (fluorometer) measurements were used to estimate standing crop (biomass).
- Primary production was measured in situ using the C^{14} assimilation, light-dark bottle technique. Bottles were incubated at depths of 0.5 m for 2-3 hours, usually between 10:00 A.M. and 3:00 P.M.
- Phytoplankton were preserved with Lugol's iodine solution for identification and enumeration under an inverted microscope.
- Preliminary zooplankton collections (Appendix C.1) were taken concurrently with this study.

B.1.5 Analysis

- Spatial distributions of various measured phytoplankton parameters were examined with respect to sampling station location relative to the generating station.

- Data for each month were entered into a canonical discriminant functional analysis to determine the relative contribution of six normally standardized variables (temperature, salinity, dissolved oxygen, chlorophyll a, phaeopigments, and productivity) to differences among the four subareas.

B.1.6 Results

- Changes in productivity values generally mirrored changes in chlorophyll levels (Figs. B.1-2 - B.1-4) except in the Gunpowder River during August where where a sharp increase in productivity was noted while chlorophyll a remained uniformly low.

- Reduced productivity and minimum chlorophyll a measurements were obtained at the discharge stations in July and August along with sharp decreases in productivity (Figs. B.1-2 and B.1-3). In September, chlorophyll a was low throughout the intake and discharge creeks (Fig. B.1-4).

- Maximum productivity was recorded in all three months at lower Gunpowder River stations.

- The surface phytoplankton community (Table B.1-1) showed characteristics typical of an oligohaline environment: 1) abundance of chlorophytes, 2) presence of many blue-greens, and 3) a general shift in dominance through the summer from diatoms to blue-greens or microflagellates.

- Subarea Differences

  -- Discriminant functional analysis plots are shown in Fig. B.1-5. Two functions were sufficient in all cases. They accounted for 96% of the variance in July, 92% of the variance in August, and 98% of the variance in September.

  -- In July, subareas were significantly different for all pairs except B and C. In August, all subarea pairs were significantly different. In September, all subareas were significantly different except A and B (Fig. B.1-5).

— Variables with the largest weight in the discriminant functional analysis were salinity and dissolved oxygen in July and August and productivity and chlorophyll in September.

— In July, the highest correlation events were between:

1) phaeopigments and salinity (-0.583; $p < 0.05$)
2) productivity and temperature (-0.582; $p < 0.05$)
3) productivity and chlorophyll (-0.506; $p < 0.05$).

In August, the highest correlation events were between:

1) temperature and salinity (0.801; $p < 0.05$)
2) chlorophyll and dissolved oxygen (0.534; $p < 0.05$)
3) chlorophyll and productivity (0.434, $p > 0.05$, not significant).

In September, the highest correlation events were between:

1) chlorophyll and phaeopigments (0.937; $p < 0.01$)
2) chlorophyll and productivity (0.762; $p < 0.01$)
3) phaeopigments and productivity (0.752; $p < 0.01$).

B.1.7 Significance and Critique of Findings

- The decrease in chlorophyll a (biomass) and productivity in the immediate discharge observed in July and August may have been due to the high temperatures (> 38 C in August) which could have inhibited photosynthesis. As the discharge cools, the warmer-than-ambient water may have stimulated local productivity away from the plant.

- Phytoplankton productivity and chlorophyll a (biomass) appeared to be higher in the Gunpowder River than in either Saltpeter or Seneca Creek during summer months.

Table B.1-1. Species and cell counts per ml of phytoplankton (filaments or colonies counted where indicated) from waters in the vicinity of the C.P. Crane generating station, July-September 1978 (from Ref. 10)

Taxa / Stations:	July				August				September			
	A08	B01	C41	D48	A09	B03	C48	D51	A12	B03	C22	D52
Cyanophyta												
*Anabaena sp.					207							
†Chroococcus sp.					2482	3930	1758					
*Cylindrospermum minimum									155	26	824	206
†Gomphosphaeria sp.		104						414				309
†Merismopedia elegans				26							26	
†M. tenuissima	827		414	103	26	103	310	26			26	309
*Oscillatoria angustissima							517			1034	20687	1655
*Spirulina sp.					26	52	103				612	106
Chlorophyta												
Ankistrodesmus falcatus				103	517	78	414	129	207		206	103
Crucigenia sp.						414						
Crucigenia tetrapedia					1448		414	414				
C. truncata					26							
Oocystis sp.								414				52
Scenedesmus acuminatus				414								
S. arcuata				207								
S. bijuga				207								
S. quadricauda				828								
Selenastrum sp.								207				206
Tetraedron minimum						52						
Tetrastrum sp.				414				517				103
Euglenophyta												
Phacus					207		129					
Bacillariophyta												
Centric												
Cyclotella sp.	103	26		26	103	26		26			103	106
Leptocylindrus danicus		104										
Melosira sulcata		52		103								
Rhizosolenia sp.										1138	325	721
Skeletonema costatum	1861	721	515	4136				2482		234		
Thalassiosira pseudonana	827	1551	1344	931				620	1034		1344	309
Pennate												
Navicula sp.	26							26				
Nitzschia sp.	52					103		103	78			
N. kutzinguiana	103								129	310		
N. longissima									26		26	26
Pleurosigma sp.										26	130	26
Cocconeis sp.									26			
Cryptophyceae												
Cryptomonas erosa	517	103			514			724	1034	1551	1344	
Dinophyceae												
Diplopsalis lenticula								26				
Peridinium sp.	414		310							103	78	
Prorocentrum minimum									310			26
Katodinium rotundatum									620			
Microflagellates	1655				931	310	517	3102	3102	3412	3090	515

†Colonies *Filaments

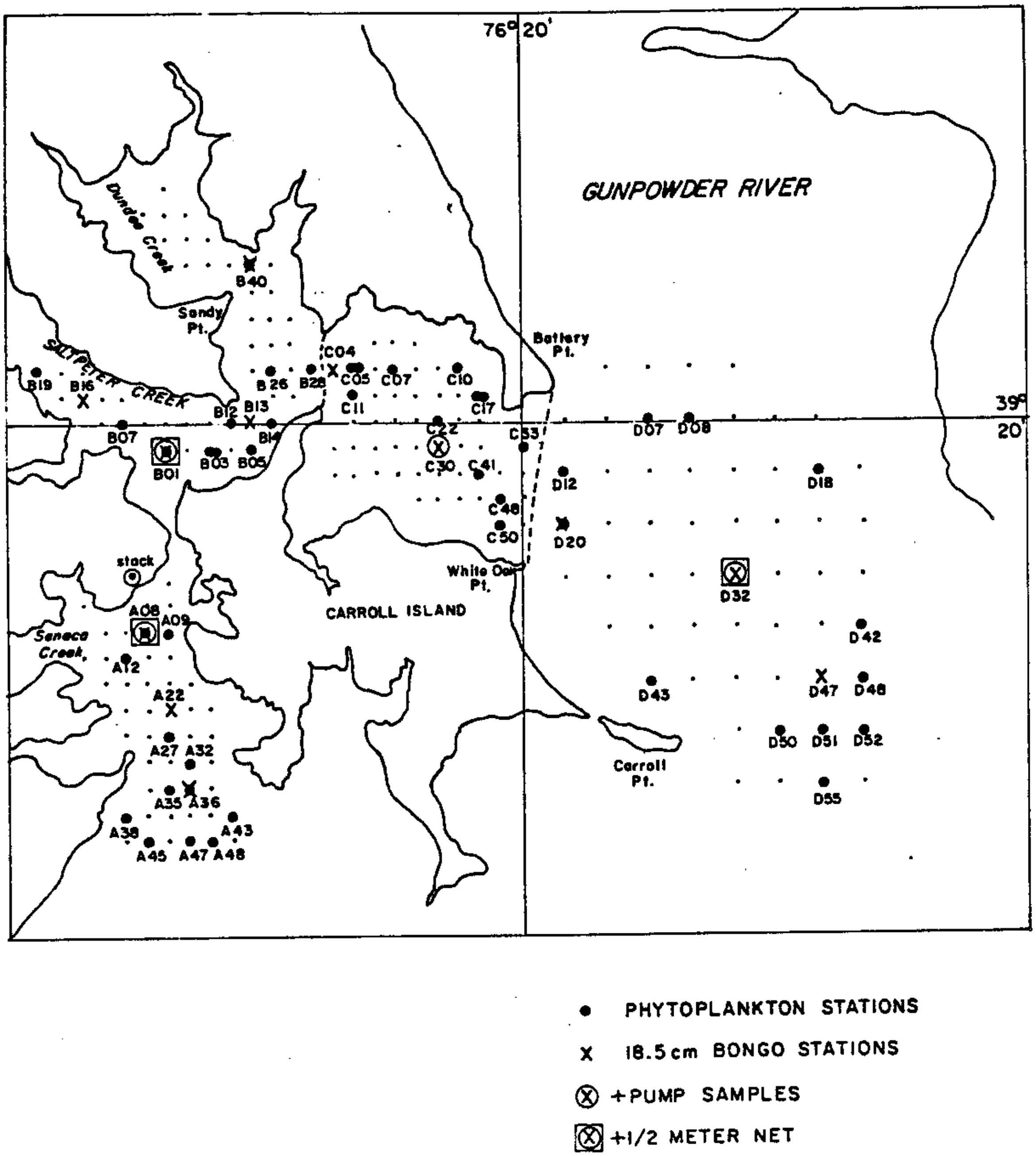

Figure B.1-1. Location of stations sampled for phytoplankton and micro-, meso-, and macro-zooplankton in the vicinity of the C.P. Crane generating station, July-September 1978 (from Ref. 10)

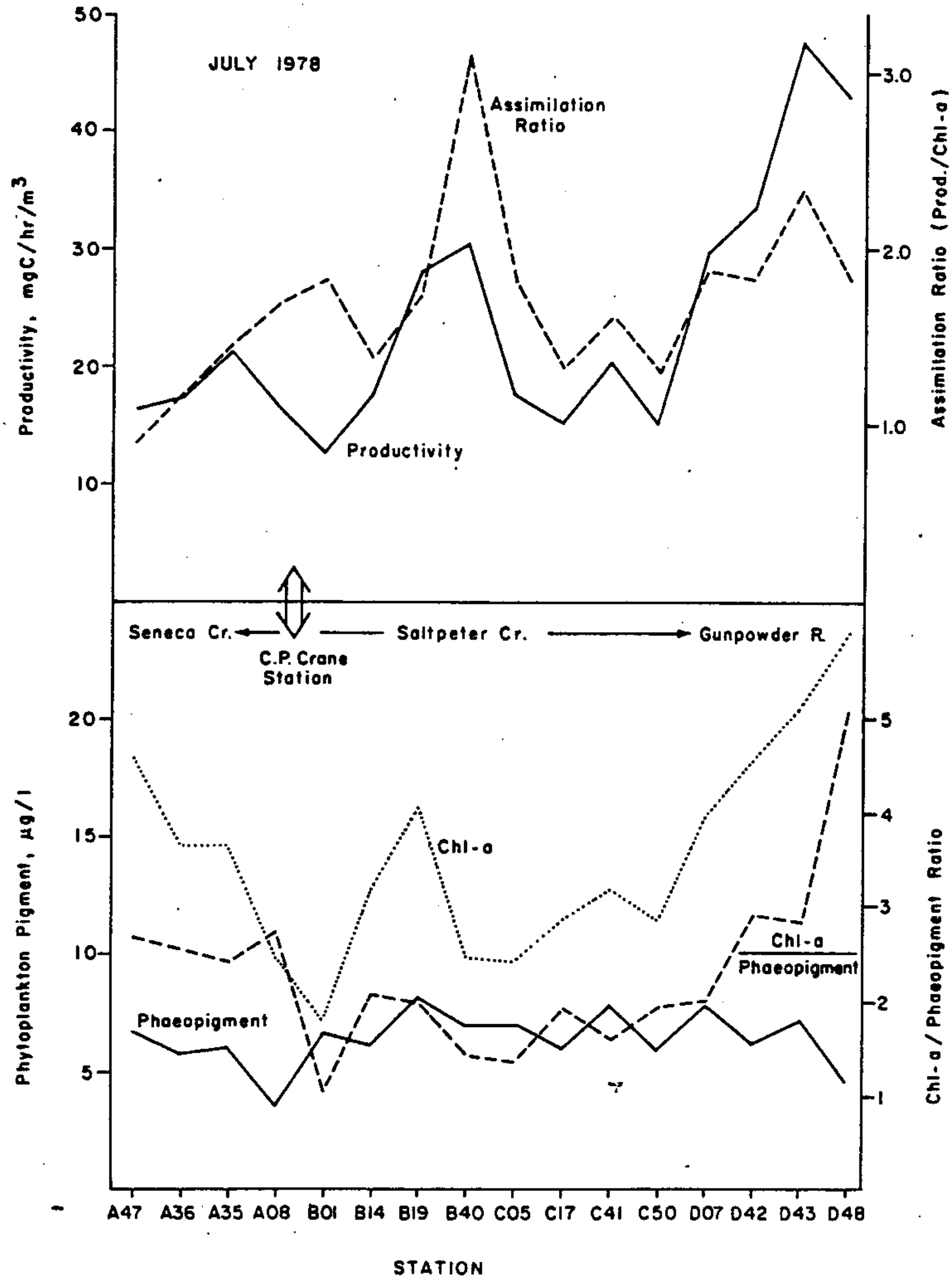

Figure B.1-2. Distribution of chlorophyll, phaeopigments, and productivity and their associated ratios, July 1978. Alignment of stations is relative to plant location (from Ref. 10)

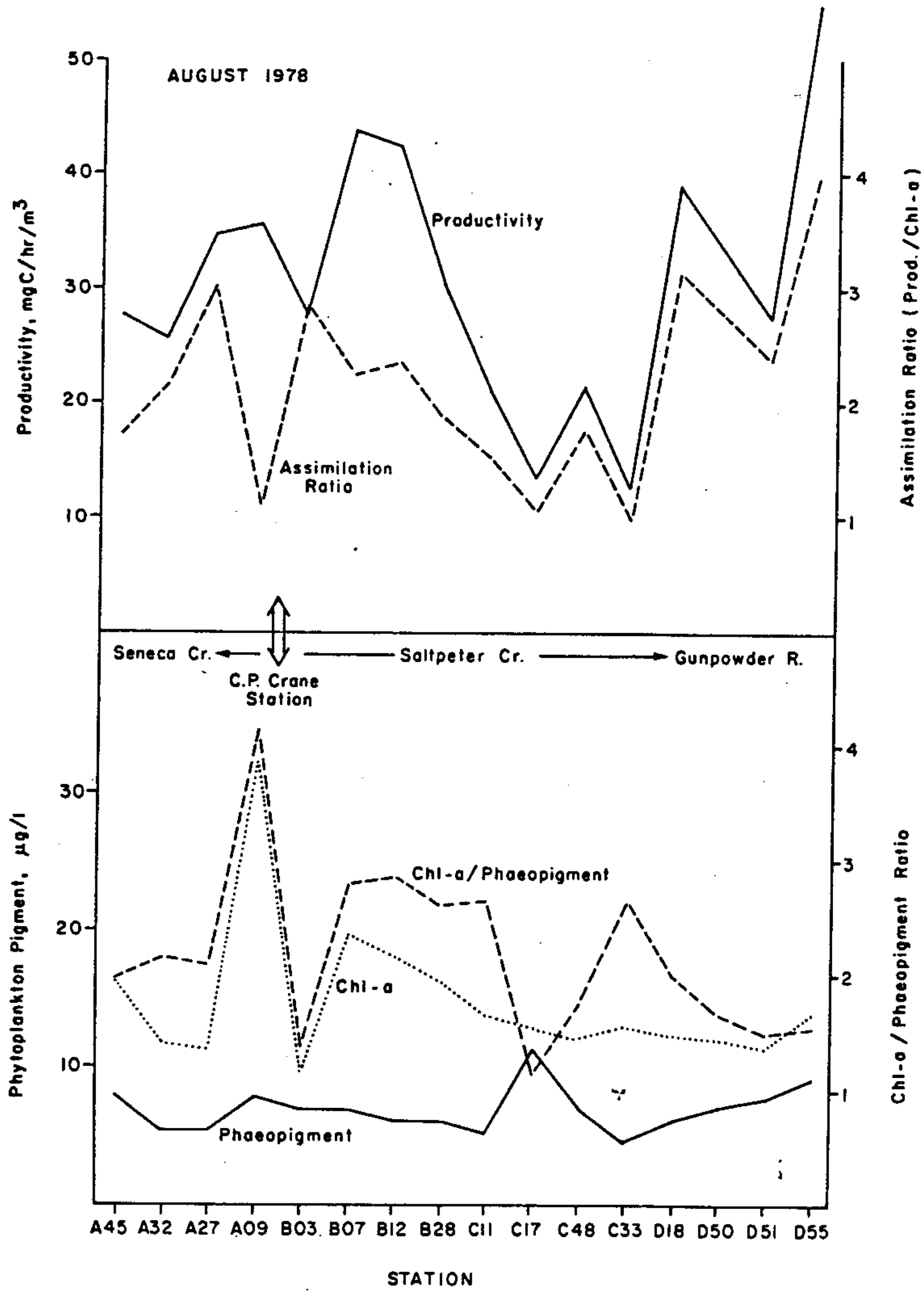

Figure B.1-3. Distribution of chlorophyll, phaeopigments, and productivity and their associated ratios, August 1978. Alignment of stations is relative to plant location (from Ref. 10)

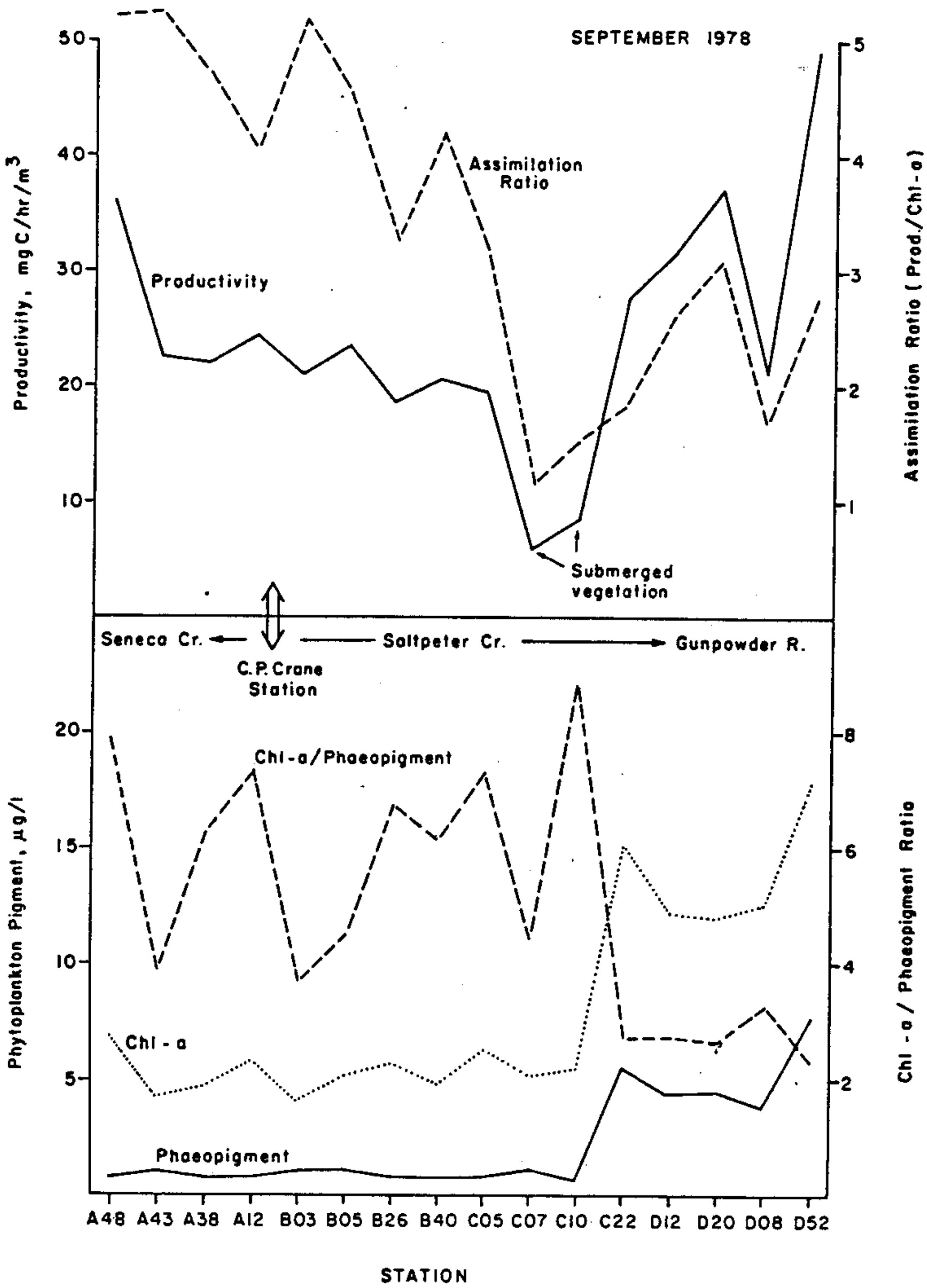

Figure B.1-4. Distribution of chlorophyll, phaeopigments, and productivity and their associated ratios, September 1978. Alignment of stations is relative to plant location (from Ref. 10)

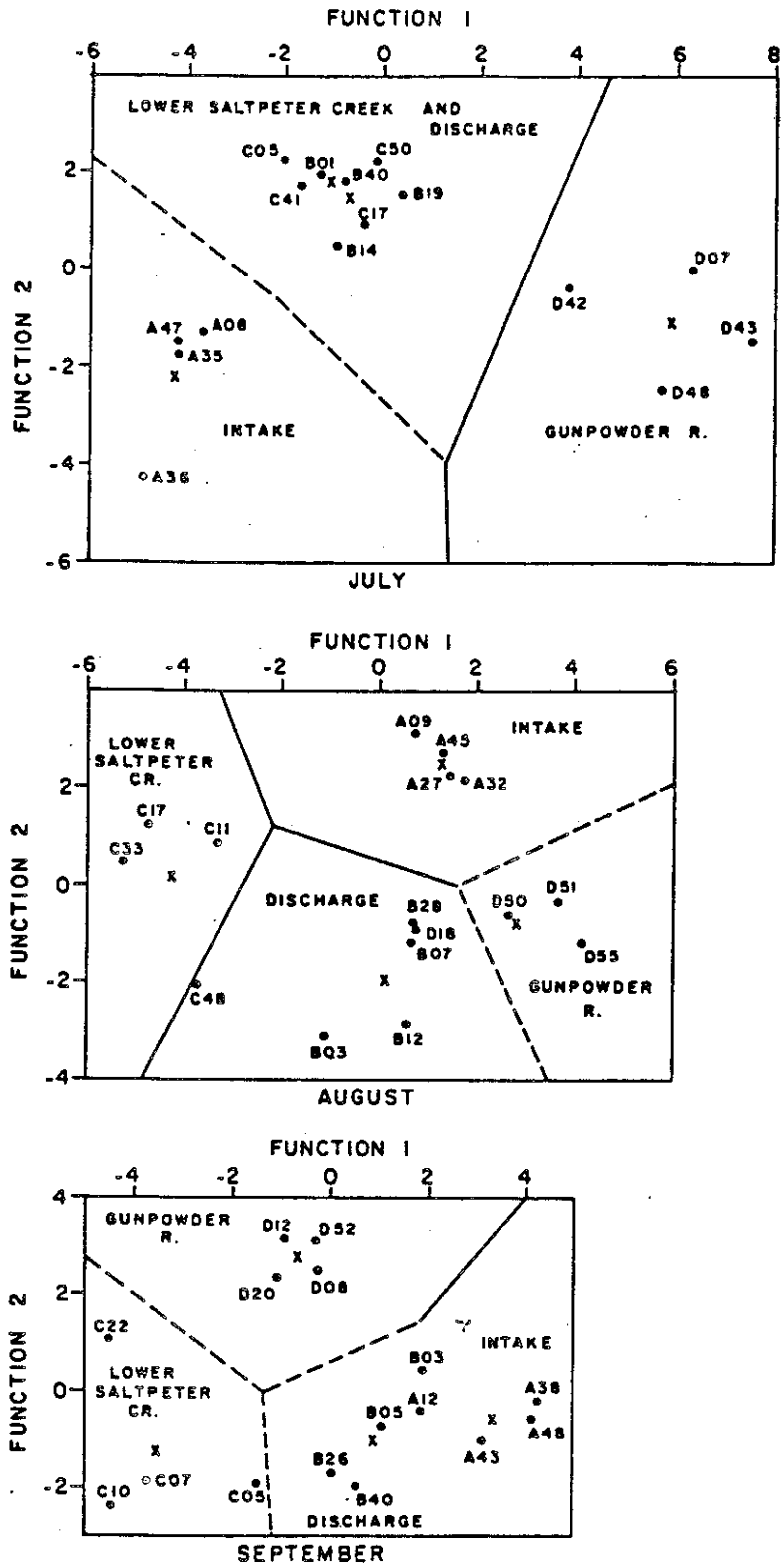

Figure B.1-5. Territorial map, subarea centroids (x), and discriminant scores (.) for each phytoplankton station, based on the first two discriminant functions of July, August, and September data (from Ref. 10)

APPENDIX B.2. SPRING PHYTOPLANKTON STUDY

(G.C. Grant and S.P. Berkowitz,
Virginia Institute of Marine Science)

B.2.1 Objective

To determine the effect of plant operations on local phytoplankton populations during spring months.

B.2.2 Data Source

Ref. 11.

B.2.3 Study History

March-June 1979.

B.2.4 Study Methods

- Sampling stations (Fig. B.2-1) were sampled once in late March, twice in April and May, and once in late June.
- Ancillary measurements included: water temperature, conductivity (salinity), dissolved oxygen, alkalinity, light penetration (secchi disc and submarine photometer), seston (gravimetric), and surface incident radiation.
- Chlorophyll (fluorometer) measurements were used to estimate standing crop (biomass).
- Primary production was measured in situ and in on-deck incubators using C^{14} assimilation light-dark bottle technique. Additional productivity measurements were made at three stations (P04, P07, and P15) at which water samples were filtered through a 20-μm screen before incubation.
- Phytoplankton were preserved with Lugol's iodine solution for identification and enumeration under an inverted microscope.
- Water samples were analyzed for the following nutrients: phosphate, silicate, ammonia, nitrite, and nitrate.
- Spring zooplankton collections (Appendix C.2) were taken concurrently with this study.

B.2.5 Analysis

- Spatial distribution of measured parameters were examined graphically with respect to distance from the plant.
- Phytoplankton stations were clustered on the basis of similarity of chlorophyll, phaeopigment, and productivity data. The resulting clusters were then used as predesignated groups in a discriminant functional analysis of eight standardized physical variables.
- Phytoplankton parameters from all samples over the sampling period were included in a cluster analysis to determine whether measured phytoplankton parameters in the discharge creek resembled ambient measurements in successive sampling periods more than measurements at other sites during the same sampling period.

B.2.6 Results

- In situ productivity measurements showed that most phytoplankton production at the C.P. Crane site occurred in the upper 0.5 m of the water column, indicating that the phytoplankton productivity at the site may be extremely light-limited.
- During the spring, phytoplankton populations were dominated by a small Skeletonema* which increased in number and importance until the bloom peak in early May. Subdominates were as follows:
  - -- Late March; an unidentified cryptophyte, Chroomonas sp., and an unidentified biflagellate
  - -- April; Ankistrodesmus sp., an unidentified centric diatom, and Nitzschia sp.
  - -- Early May; Chroomonas sp., Nitzschia sp., and an unidentified flagellate.
  - -- Late May; Nitzschia sp., Merismopedia sp., and Ankistrodesmus sp.
  - -- Late June; Chroomonas sp., Nitzschia sp., and an unidentified centric diatom.

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* Skeletonema was believed to have been misidentified in this study and was referred to as Melosira in the final draft.

- Chlorophyll a distributions (or phytoplankton biomass) generally mirrored productivity patterns, resulting in assimilation ratios that followed productivity trends.

- At stations where samplings were conducted at the surface, mid-depth, and bottom, vertical homogeneity was observed in box-incubated productivity, taxonomy, and pigment measurements.

- Changes in phytoplankton productivity and biomass (chlorophyll a) in the power plant discharge appeared to depend on ambient conditions. In early spring, when temperatures and productivity in the Chesapeake Bay generally were low, productivity increased along Seneca Creek to the plant's intake, decreased sharply in the immediate discharge, then recovered in lower Saltpeter Creek. This trend was reversed in late spring when ambient waters were warmer (above 19C) and highly productive: productivity decreased along Seneca Creek to the plant's intake and then increased sharply in the immediate discharge (Figs. B.2-2 through B.2-7).

- Cluster analysis of stations showed a strict seasonal separation indicating that changes in phytoplankton parameters in the study area were dominated by seasonal changes and not by heated effluent (Fig. B.2-8).

- Heating of water passed through the plant in late March resulted in productivity and phytoplankton biomass in discharge waters that was more similar to early April than late March ambient conditions.

- All 91 spring phytoplankton stations were clustered on the basis of similarity in surface measurements of chlorophyll a, phaeopigments, and productivity. The resulting four clusters (Fig. B.2-8) were used as preclassified groups in a discriminant function analysis using physical variables. Three of the four biological station groups were well separated on the basis of physical characteristics (84% of the stations correctly classified) (Fig. B.2-9). Important physical variables in the first two functions were mean water temperature and bottom dissolved oxygen.

B.2.7 Significance and Critique of Findings

- The power plant appears to affect phytoplankton productivity and abundance (chlorophyll a) in the water around the immediate discharge. The effect may be dependent upon ambient conditions. The increase in productivity at the discharge stations in late spring may be limited to temperate or bloom conditions, since results from summer 1978 (Appendix B.1) showed a sharp decrease in productivity at the most immediate discharge areas sampled.

- In a combined seasonal analysis of productivity and pigment levels, seasonal effects generally overshadowed those due to plant operations.
- Little information was gained from the nutrient data due to inconsistent results in the first- and second-day replicates, difficulties in measuring low concentrations, and limited seasonal sampling.

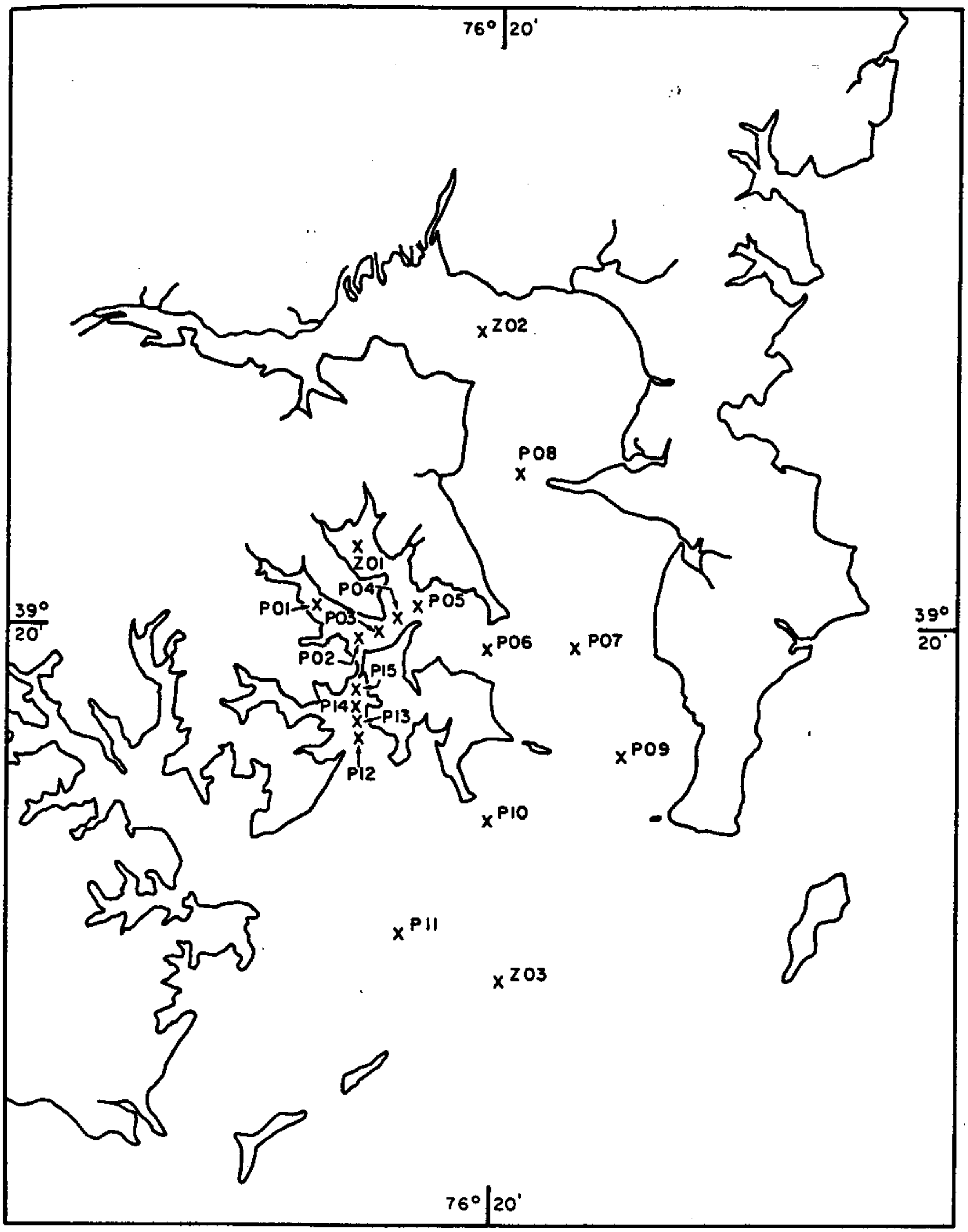


Figure B.2-1. Location of stations sampled in the vicinity of the C.P. Crane generating station, March-June 1979. Station P02 was located in the immediate discharge (Saltpeter Creek); P15 was in the immediate intake (Seneca Creek) (from Ref. 11)

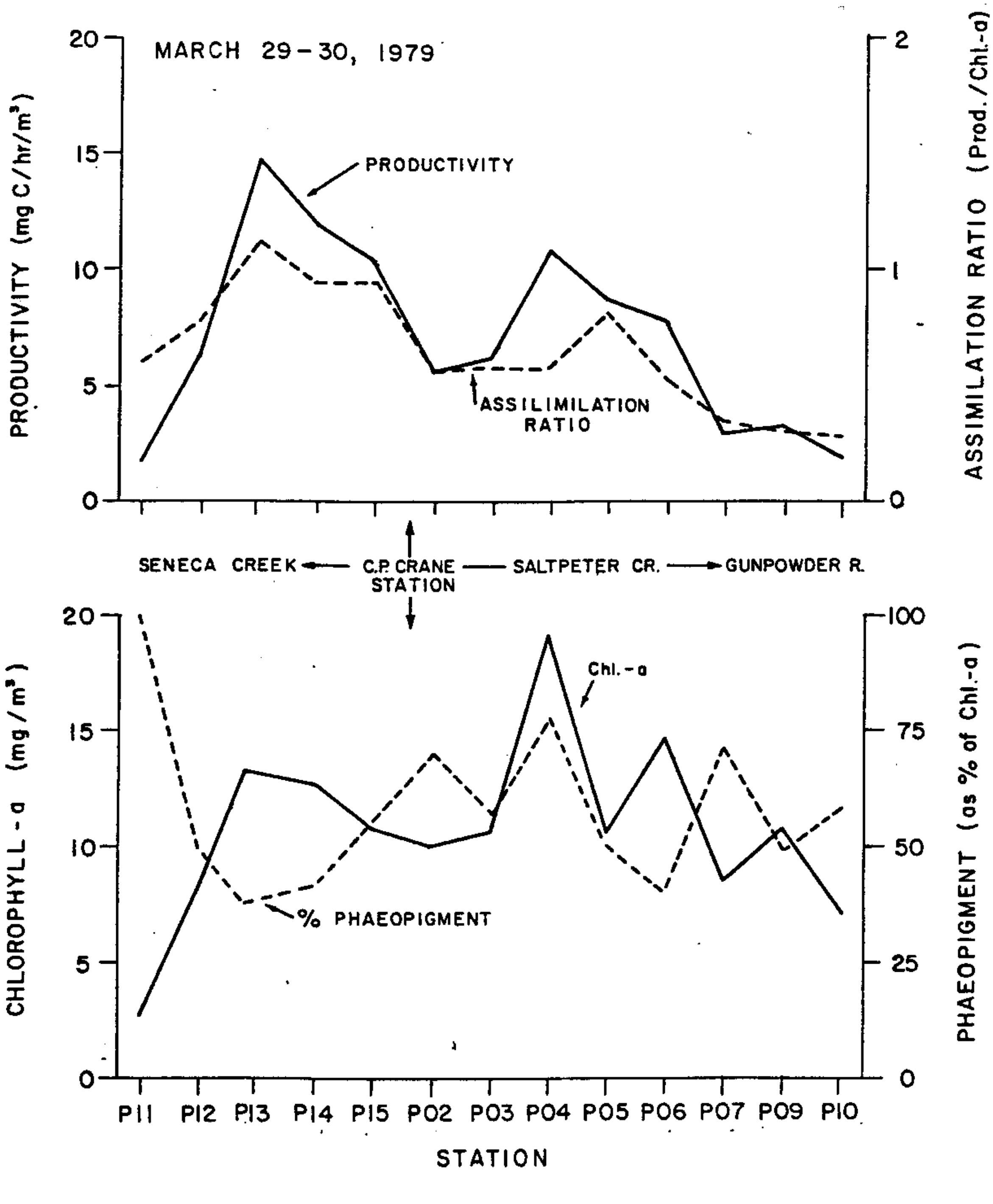


Figure B.2-2. Distribution of chlorophyll, phaeopigment, productivity, and assimilation ratio, March 29-30, 1979. Alignment of stations is relative to plant location; those stations not in intake or directly in path of effluent were omitted (from Ref. 11)

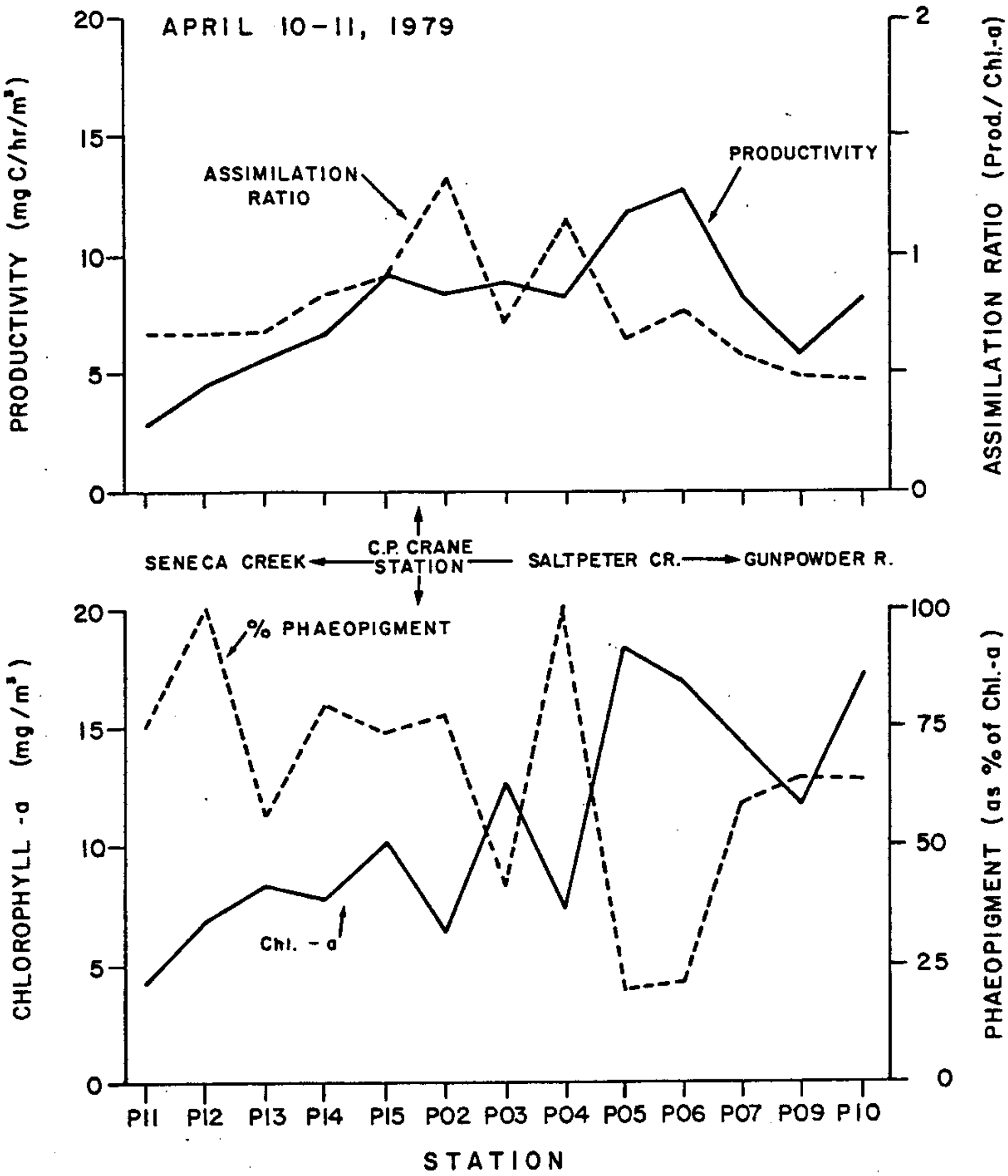


Figure B.2-3. Distribution of chlorophyll, phaeopigment, productivity, and the assimilation ratio, April 10-11, 1979 (from Ref. 11)

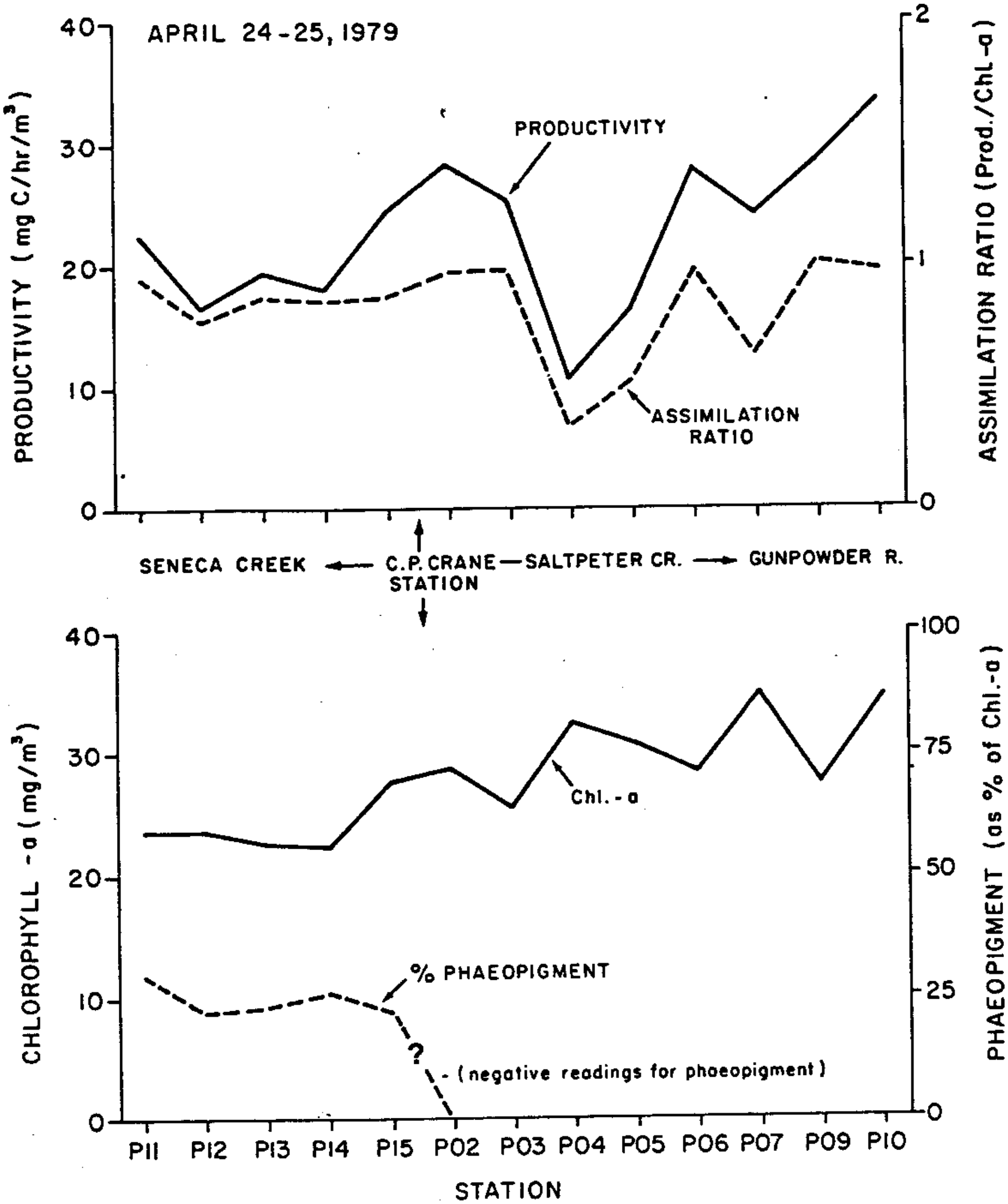


Figure B.2-4. Distribution of chlorophyll, phaeopigment, productivity, and the assimilation ratio, April 24-25, 1979 (from Ref. 11)

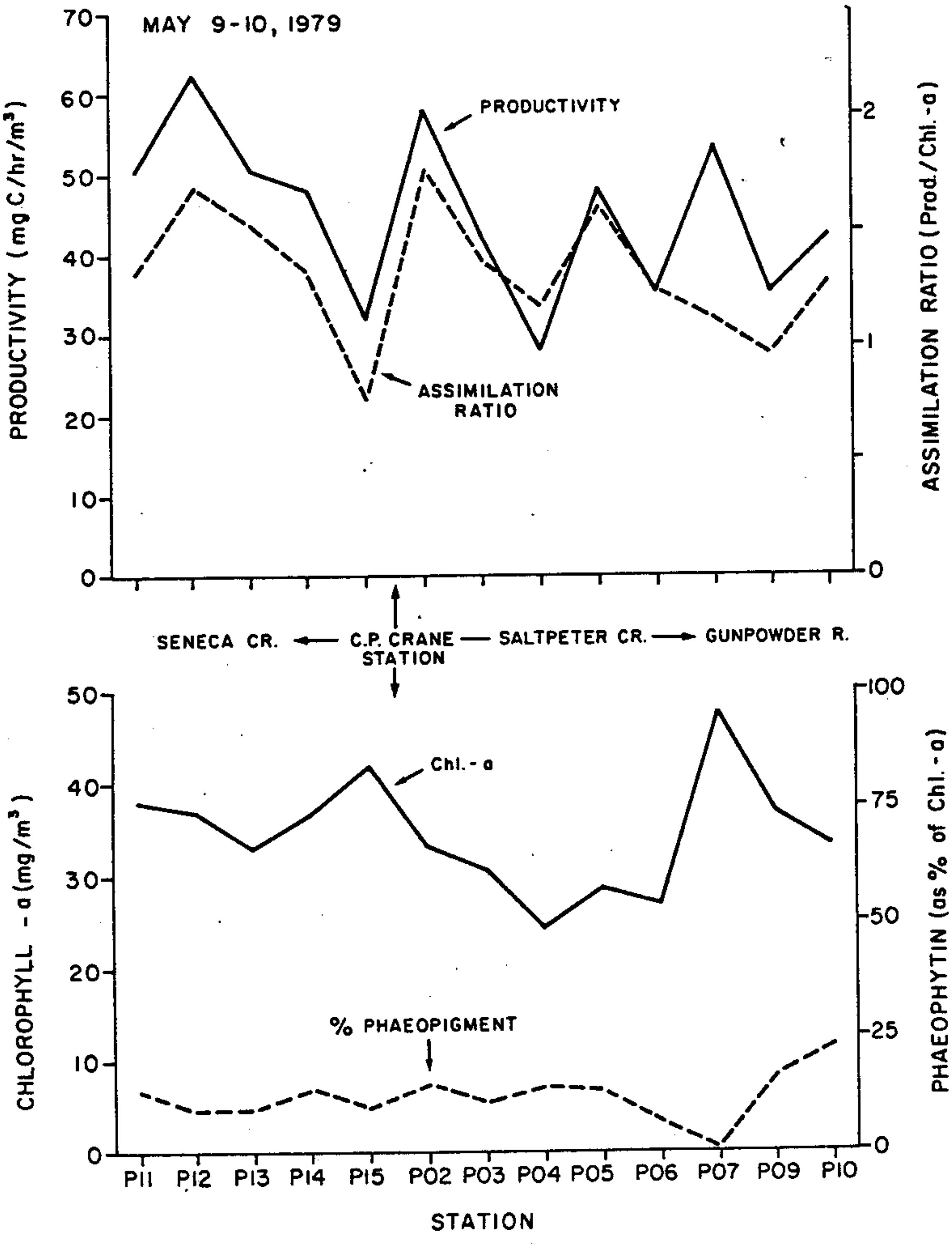


Figure B.2-5. Distribution of chlorophyll, phaeopigment, productivity, and the assimilation ratio, May 9-10, 1979 (from Ref. 11)

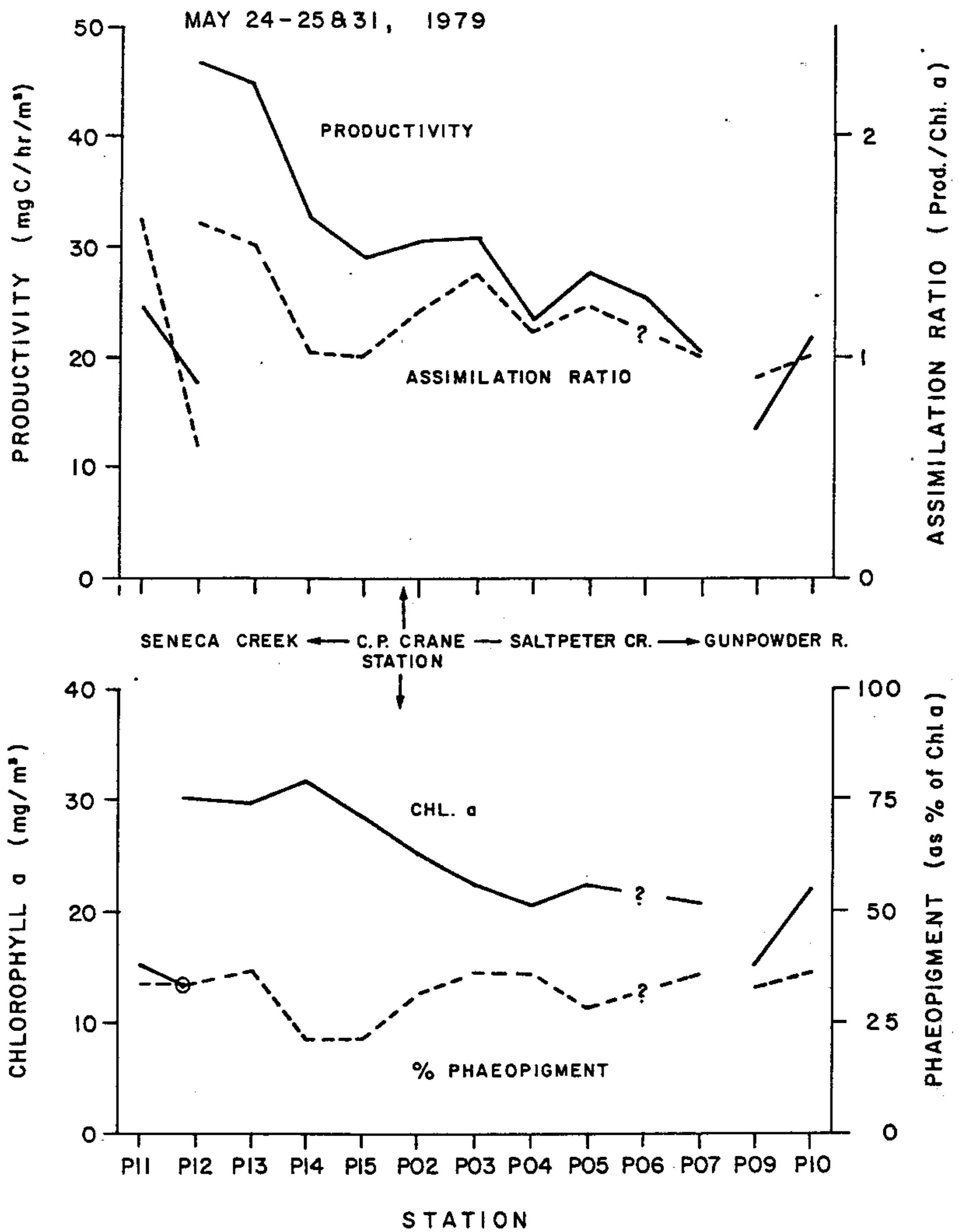


Figure B.2-6. Distribution of chlorophyll, phaeopigment, productivity, and the assimilation ratio, May 24-25 and 30, 1979. Data for Station P06 is missing; Stations P09, P10, P11, and P12 (second time) were sampled on May 31, 1979 (from Ref. 11)

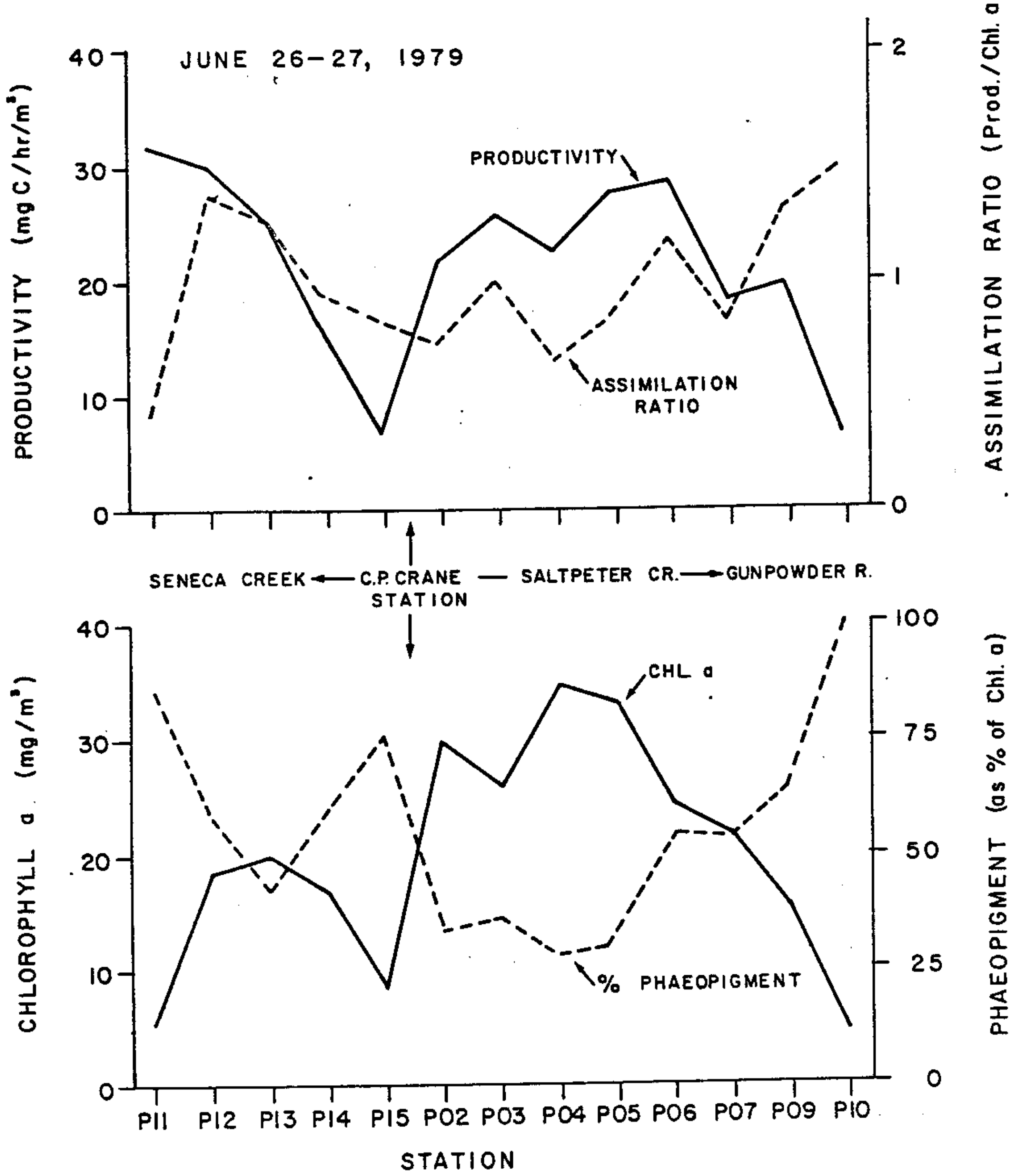


Figure B.2-7. Distribution of chlorophyll, phaeopigment, productivity, and the assimilation ratio, June 26-27, 1979 (from Ref. 11)

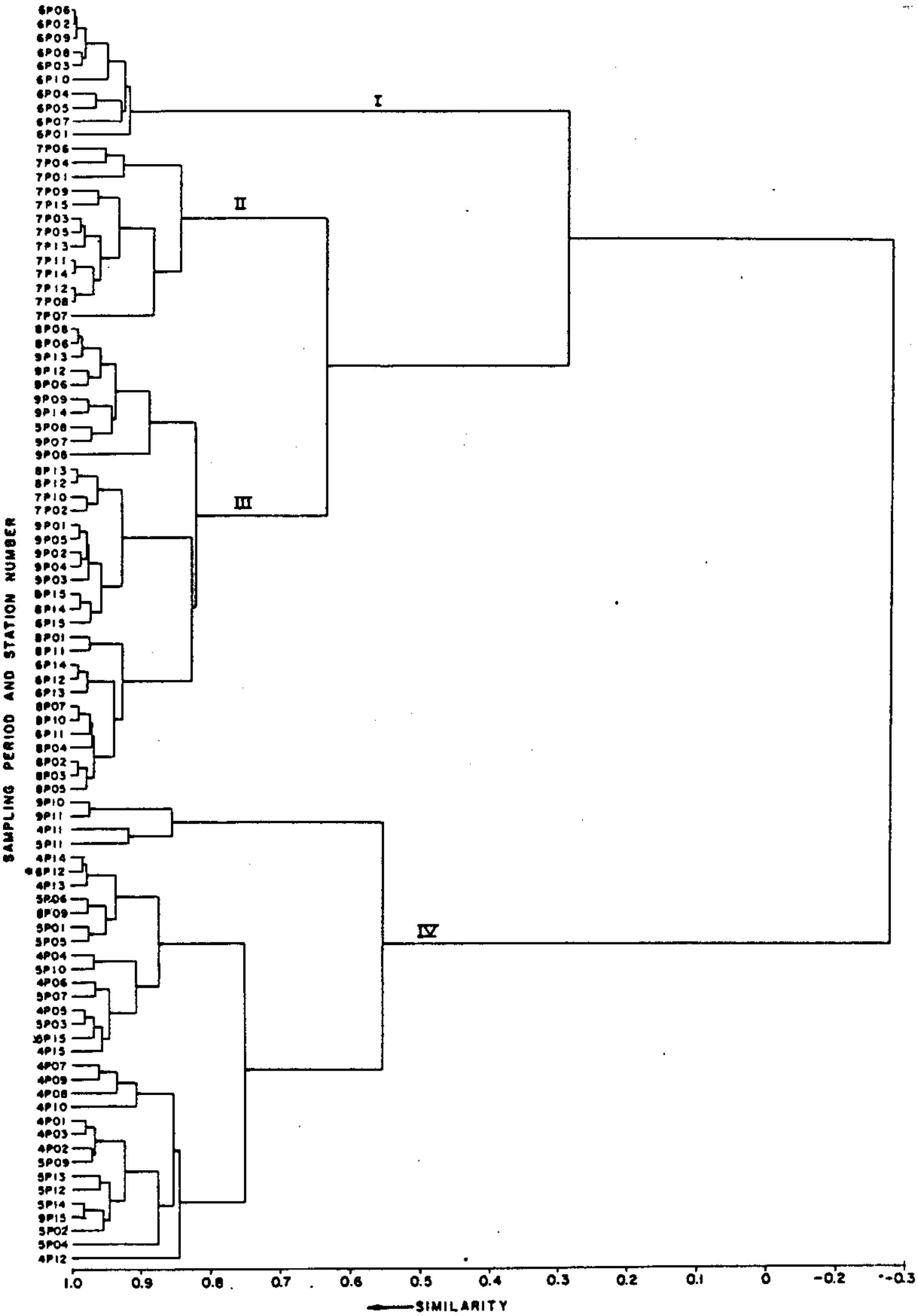


Figure B.2-8. Clustering of spring 1979 phytoplankton stations on the basis of surface chlorophyll and phaeopigment (screened and total samples) and surface productivity (box-incubated). Sampling periods (indicated by digits preceding station number): 4 - March 29-30; 5 - April 10-11; 6 - April 24-25; 7 - May 9-10; 8 - May 24-25 and 31; 9 - June 26-27. Asterisk indicates a second sampling of P12 on May 31 (from Ref. 11)

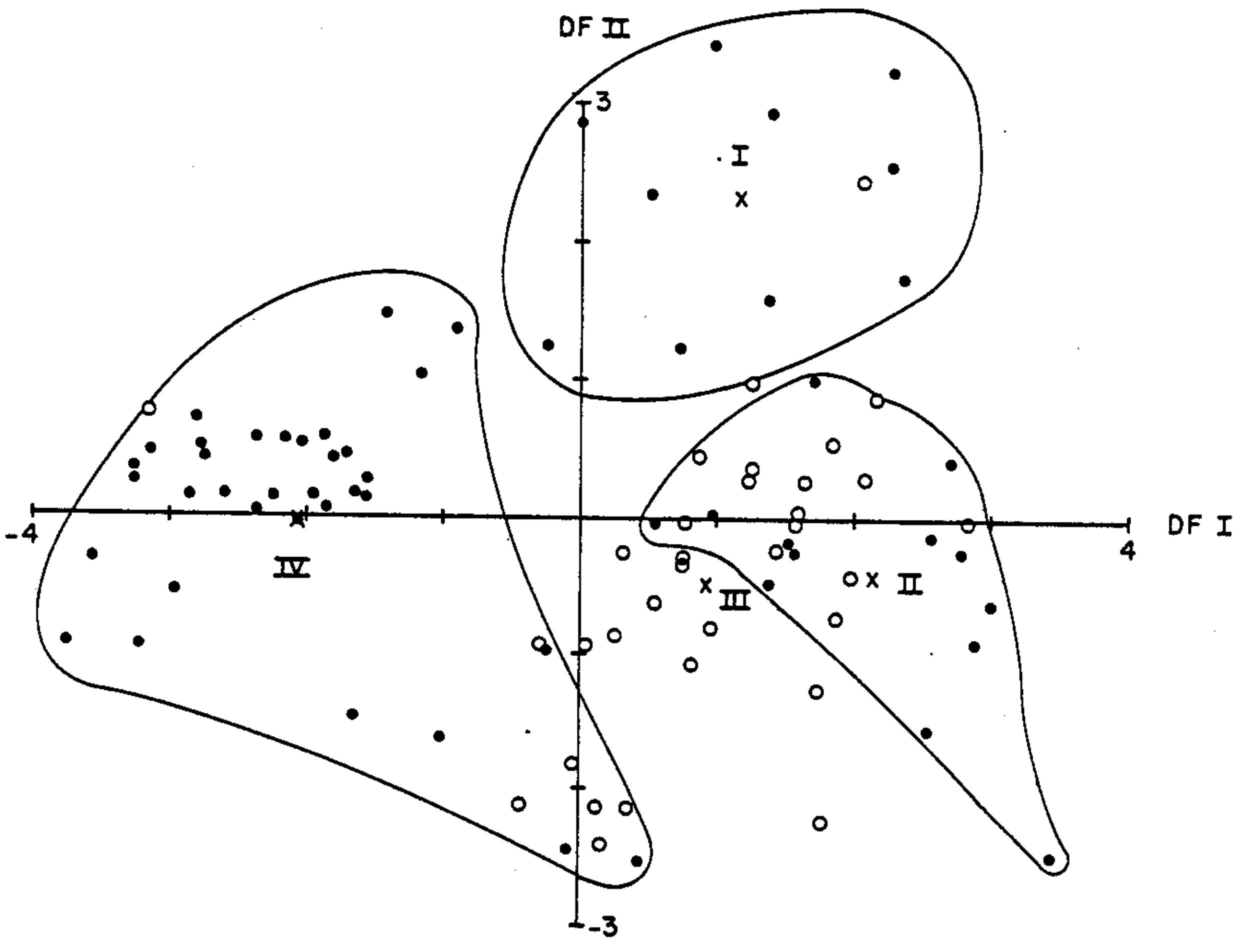


Figure B.2-9. Separation of the sample groups obtained from phytoplankton biomass and productivity clustering on the first two discriminant functions of eight environmental variables. Group centroids are indicated with X's; open circles are samples in the poorly separated Group III (from Ref. 11)

APPENDIX B.3. PHYTOPLANKTON STUDY

(K.G. Sellner, L.A. Lyons, R.K. Mahoney, M.M. Olson and E.S. Perry; Academy of Natural Sciences of Philadelphia)

B.3.1 Objective

To determine the effect of plant operations on phytoplankton populations in the surrounding waters.

B.3.2 Data Source

Ref. 12.

B.3.3 Study History

July 1979-March 1980.

B.3.4 Methods

- Duplicate composite surface samples were collected monthly at eight stations (Fig. B.3-1). The composites were obtained by pooling 20 or more 1-liter samples taken along a short transect.
- Subsamples of the large composite samples were taken to determine biomass (chlorophyll), in situ surface (1-5 cm below the surface) productivity (nanoplankton and whole water), and nutrient concentrations (NO_2, NO_3, NH, and ortho-PO_4).
- Composite subsamples were fixed (I_2-KI) and preserved (buffered formalin) for identification and enumeration.
- In the entrainment study, composite intake samples were obtained by mixing equal amounts of water from the surface and 2- and 4-meter depths.

B.3.5 Analysis

- A nested-factorial analysis was used, with stations and data as fixed cross-classified factors and composite samples and subsamples as nested factors. An analysis of variance (ANOVA) tested the main factors and interactions against an error term defined by the among-composite-sample variation. This error term gives an estimate of variation within a heterogeneous environment.

- If ANOVA indicated significant differences, the sources of these differences were investigated with plots and the Student-Newman-Keuls procedure.

- Data from intake-discharge stations were analyzed separately from the nearfield data.

- Nanoplankton and whole-water analyses were conducted independently.

- Shannon-Wiener diversity indices were used to investigate seasonal and spatial differences in community structure among stations.

B.3.6 Results

- In general, entrainment through the plant appeared to enhance absolute photosynthetic rates and efficiency when ambient intake water temperatures were less than 25.5C and the ΔT was less than 6.7C.

- The stimulation of primary productivity was observed at both the discharge and upper Saltpeter Creek in all months sampled except September. Plant operations could not be identified as altering productivity (absolute rates and assimilation ratios) in the Gunpowder River (Fig. B.3-2, a-i).

- Neither chlorophyll *a* nor cell numbers were significantly altered during passage through the plant.

- Chlorophyll *a* concentrations in both size fractions increased from upper Saltpeter Creek to a maximum in the Gunpowder River; maximum concentrations were observed in September; minimums, in February.

- Seasonal changes in community composition were marked by a predominance of blue-green algae from July through September and in December. Diatoms, particularly *Skeletonema* sp. and *Cyclotella* sp., dominated during the remaining months, except in March, when flagellates were most abundant.

- Nanoplankton represented most of the biomass and productivity in the phytoplankton community. In the entrainment studies, microflagellate densities decreased substantially in September only. This decline was accompanied by enhanced carbon fixation, assimilation rate, and chlorophyll-*a* concentrations.

- Nutrient concentrations were not significantly different among stations. Higher NH_4^+ concentrations were noted at Station P3 compared to P1 in July, August, and March and, in addition, when compared to other Saltpeter Creek stations, in February. Nitrate concentrations were also elevated at P3 and P4 in July. Increases in the inorganic nitrogen pools should enhance plant productivity downstream. However, enhanced algal productivity and biomass downstream may also be due to other factors, including temperature.

B.3.7 Significance and Critique of Findings

- During July and August in this study, enhanced productivity was found in the discharge (Table B.3-1) region. Grant and Berkowitz (Appendix B.1), on the other hand, found a decrease in productivity and chlorophyll *a* (biomass) in the immediate discharge region (Fig. B.1-2 and Table B.1-1). The different results were believed to be attributed to differences in ambient temperature, ΔT, and/or community structure. It appears that power plant operations enhance productivity in the discharge region during all but the most extreme summer periods, when discharge temperatures approach or exceed the tolerance limits of some species.

- Since no direct indications of plant impact in the lower Gunpowder River were found, the results suggest that any effects were limited to the immediate discharge area.

Table B.3-1. Whole-water carbon fixation rates ($\mu g\ C\ l^{-1}\ h^{-1}$), assimilation ratios ($\mu g\ C\ \ g\ chl\ a^{-1}\ h^{-1}$), and chlorophyll *a* concentrations ($\mu g\ l^{-1}$) in the vicinity of the C.P. Crane generating station for 1978-1979. Superscripts a, b, and c refer to studies by Sellner et al. (Ref. 12); Ecological Analysts, Inc. (Ref. 5); and Grant and Berkowitz (Refs. 10 and 11).

Month	Station	$^{14}C^a$	$^{14}C^b$	$^{14}C^c$	AR^a	AR^b	AR^c	chl^a	chl^b	chl^c
Jan	P1	5.1			0.4			13.0		
	P2	5.4			0.9			6.5		
	P3	29.6			2.2			13.5		
	P4	11.4	12.5		0.9	11.4		13.3	1.1	
	P5	11.9	30.8		0.6	5.3		18.7	5.0	
	P6	6.2	2.7		0.3	3.9		20.4	0.7	
	P7	6.9			0.4			15.5		
	P8	9.4	23.0		0.6	5.6		15.0	4.1	
Feb	PI	1.6			0.2			7.9		
	PD	6.4			0.6			10.4		
	P2	2.5			0.6			6.4		
	P3	12.4			3.0			6.9		
	P4	3.9			0.5			9.3		
	P5	-			-			-		
	P6	-			-			-		
	P7	-			-			-		
	P8	-			-			-		
March	P1	2.8		5.6	0.2		0.5	13.5		10.9
	P2	11.8		4.8	1.1		0.4	12.4		11.2
	P3	10.1		5.6	0.8		0.6	12.2		10.0
	P4	5.0	5.1	6.9+	0.2	2.7	0.5+	25.9	1.9	14.9+
	P5	1.9	3.5	7.6	0.1	2.1	0.5	22.9	1.7	14.8
	P6	3.9	1.9	3.0	0.2	1.7	0.3	22.3	1.1	8.7
	P7	5.2		1.6	0.2		0.2	26.7		8.5
	P8	4.3	3.0	1.9	0.2	2.7	0.3	28.6	1.1	7.1
Apr	P1			3.45/13:45			0.34/0.40			10.02/27.70
	P2			17.59/22.22			1.05/1.13			16.74/19.65
	P3			8.46/28.09			1.33/0.97			6.35/28.89
	P4		66.4	8.96/25.21		3.6	0.71/0.98		18.7	12.56/25.67
	P5		21.5	12.80/27.95		1.0	0.76/0.98		21.4	16.89/28.52
	P6		53.4	12.32/22.97		1.4	0.47/0.79		37.5	25.94/29.02
	P7			6.33/42.43			0.45/1.21			14.11/34.97
	P8		16.8	8.06/		1.2	0.47/		13.6	17.20/
May	P1			73.38/30.38			1.75/1.06			41.91/28.64
	P2			36.75/30.32			1.31/1.66			28.15/18.22
	P3			57.86/30.40			1.76/1.21			32.86/25.05
	P4		195.5	41.88/30.91		5.4	1.36/1.38		36.1	30.88/22.32
	P5		177.2	35.12/25.17		5.8	1.25/		30.8	28.15/
	P6		337.7	60.01/26.84		5.2	1.54/1.24		65.4	39.06/21.70
	P7			98.49/40.44			2.07/1.94			47.62/20.83
	P8		276.0	42.34/11.96		3.9	1.27/0.54		70.3	33.36/21.95
June	P1			29.89			3:58			8.35
	P2			27.47			0.81			33.98
	P3			21.46			0.72			29.88
	P4		138.1	25.66		8.6	0.99		16.1	25.92
	P5		163.0	28.15		6.4	1.17		25.3	24.06
	P6		159.6	14.04		5.5	1.23		29.2	27.78
	P7			23.74			1.09			21.70
	P8		135.8	6.51		6.5	1.48		20.9	4.41

+ average of stations PO3 and PO4

Month	Station	$^{14}C^a$	$^{14}C^b$	$^{14}C^c$	AR^a	AR^b	AR^c	chl^a	chl^b	chl^c
July	P1	70.2		16.7	-		1.7	-		9.9
	P2	111.0		28.0	8.0		1.7	17.6		16.1
	P3	84.4		12.9	4.5		1.8	19.3		7.1
	P4	96.1	157.8	17.6	4.4	4.7	1.4	23.9	33.7	12.7
	P5	113.5	114.8	20.5	4.6	5.1	1.6	24.5	22.4	12.7
	P6	138.8	132.5		4.8	5.2		29.0	25.3	
	P7	134.2		29.6	4.3		1.9	31.5		15.8
	P8	137.5	189.8		4.8	3.3		28.6	56.7	
August	P1	83.2		35.5	4.6		1.1	19.2		32.2
	PD	147.6			10.7			13.0		
	P2	92.6		44.0	7.2		2.3	12.8		19.5
	P3	121.8		27.5	7.1		2.9	18.1		9.6
	P4	157.7	250.1	42.7	7.5	8.1	2.4	21.6	30.8	18.0
	P5	174.1	247.9	13.4	11.6	7.7	1.1	15.2	32.4	12.7
	P6	52.4	272.7		4.6	5.8		13.8	47.1	
	P7	78.3		40.0	4.1		3.2	18.9		12.4
	P8	105.3	253.4		4.5	6.7		23.5	38.0	
Sept.	P1	62.3			2.9			27.3		
	PD	94.9			3.6			26.7		
	P1	79.9		24.2	2.3		4.1	34.2		5.9
	PD	178.6			4.0			44.7		
	P2	24.8			1.0			32.3		
	P3	19.4		21.0	0.5		5.1	41.4		4.1
	P4	7.8	94.9	23.4	0.3	3.3	4.5	30.5	29.1	5.2
	P5	8.8	136.1	27.7	0.2	4.4	1.8	45.1	30.9	15.1
	P6	156.2	195.0		2.5	4.4		60.2	44.5	
	P7	104.8		21.1	2.1		1.7	50.2		12.6
	P8	79.6	164.2		1.8	4.8		43.3	34.0	
Oct.	P1	10.0			0.9			10.9		
	PD	44.6			2.3			19.7		
	P2	21.1			3.4			6.4		
	P3	36.8			3.4			11.7		
	P4	42.1	26.7		3.0	2.0		14.9	13.1	
	P5	16.8	20.1		2.3	2.4		7.8	8.4	
	P6	18.1	15.7		3.4	1.9		9.5	8.4	
	P7	28.2			2.0			13.9		
	P8	20.5	34.2		1.1	1.5		18.3	22.8	
Nov.	P1	29.3			1.8			18.6		
	P2	32.2			1.3			24.8		
	P3	67.9			3.6			18.5		
	P4	38.8	25.8		1.9	1.6		20.0	15.7	
	P5	15.8	36.4		0.8	1.6		18.9	22.1	
	P6	48.5	36.8		1.0	0.9		46.5	39.6	
	P7	16.7			0.2			27.2		
	P8	16.3	34.1		0.7	1.0		23.5	32.6	
Dec.	P1	14.6			1.1			13.3		
	P2	16.4			1.2			14.2		
	P3	-			-			12.0		
	P4	25.0	28.1		2.0	2.4		12.5	11.8	
	P5	26.1	29.4		1.6	1.8		16.2	16.7	
	P6	21.0	32.5		1.1	1.7		19.6	19.2	
	P7	18.8			0.9			20.5		
	P8	8.7	26.6		0.8	2.2		11.0	12.3	

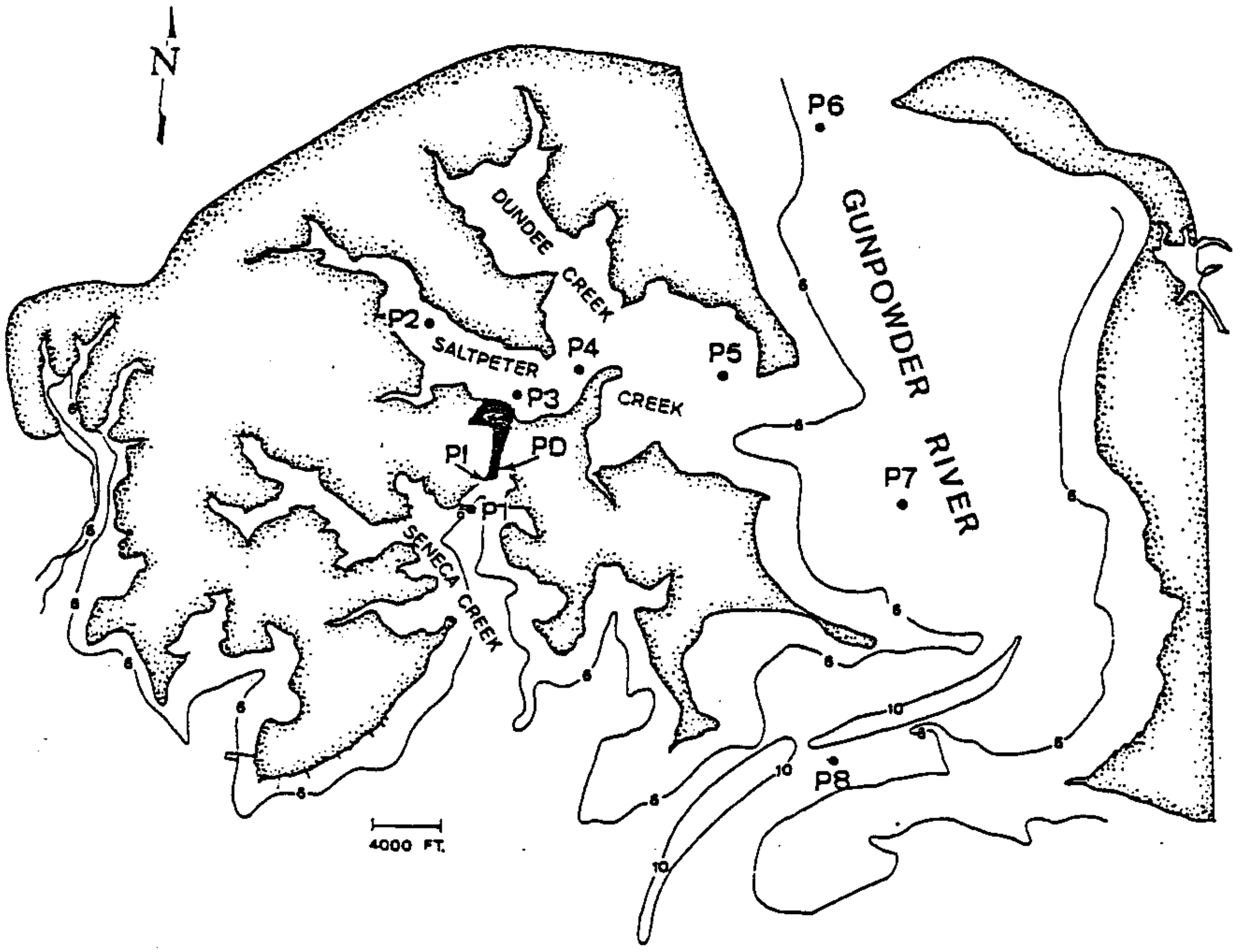
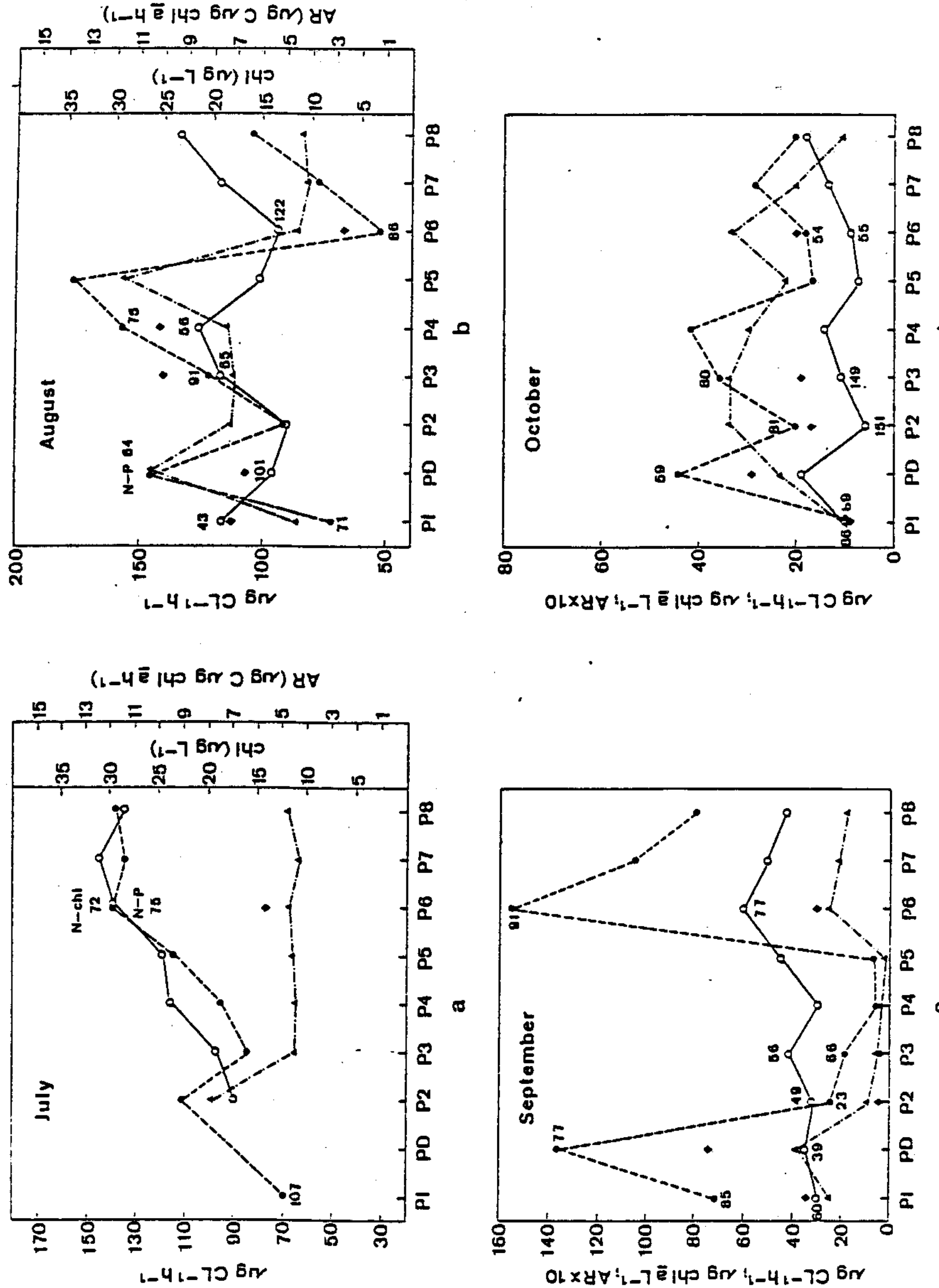
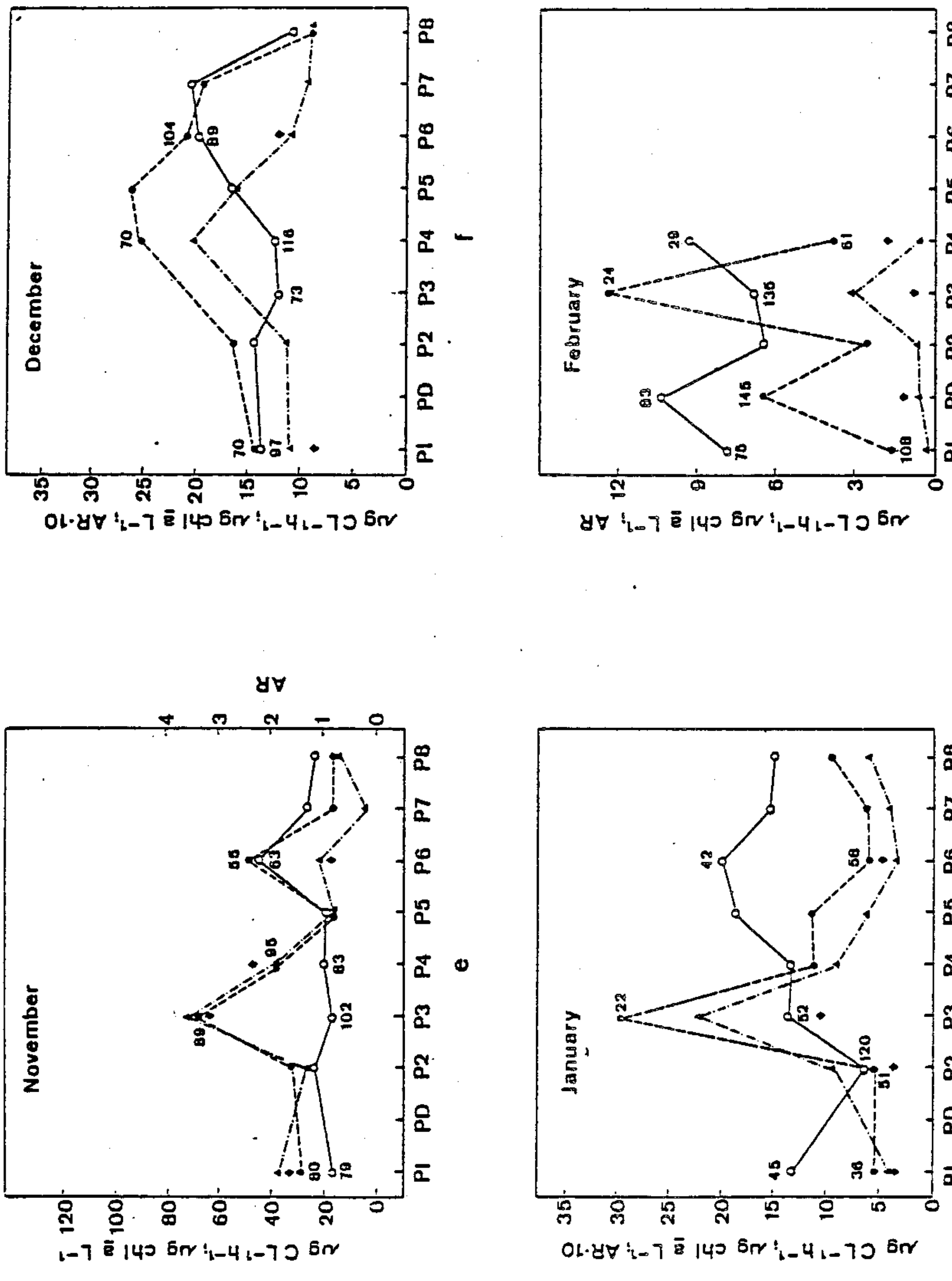
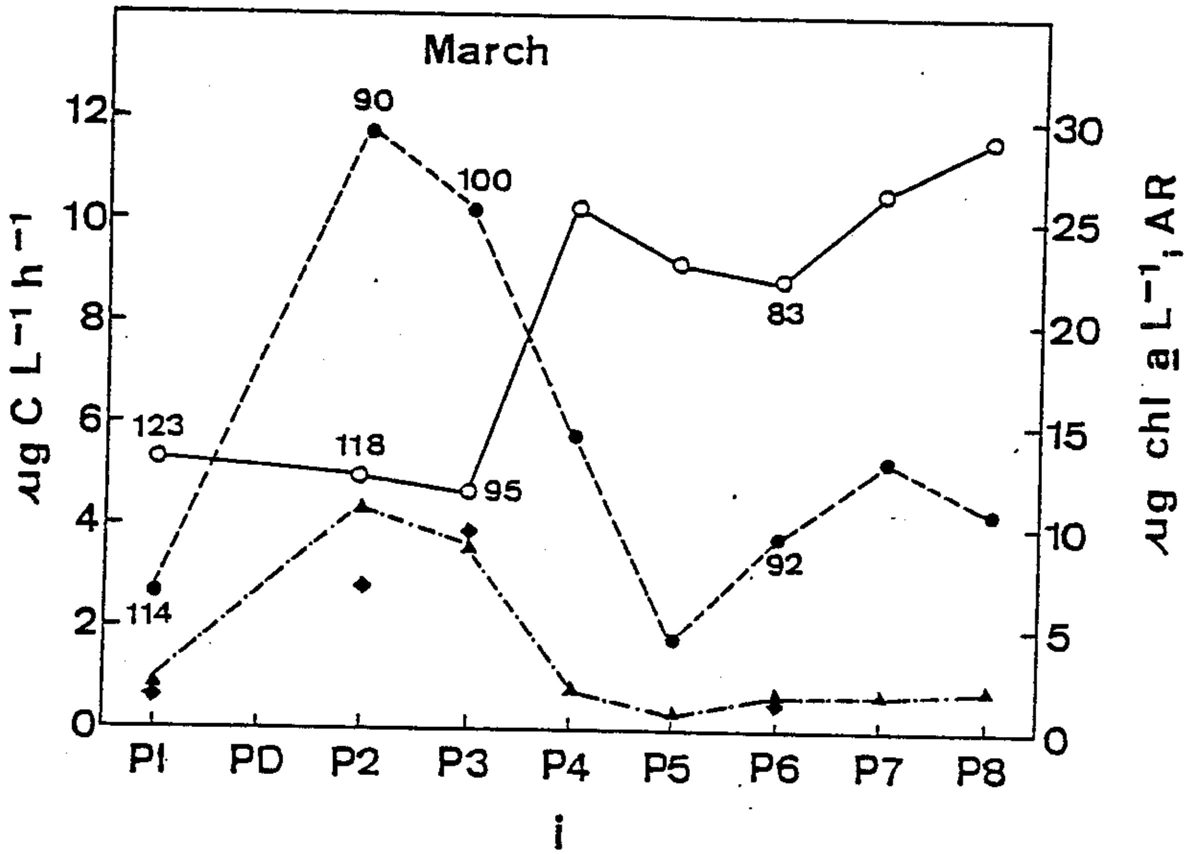


Figure B.3-1. Phytoplankton and nutrient sampling stations in the vicinity of the C.P. Crane generating station, July 1979 through March 1980. (Dark area represents discharge canal.) (from Ref. 12)

Figure B.3-2, a-i. Whole-water (●) and nanoplankton carbon fixation rates (μg C l^{-1} h^{-1}); whole-water (o) and nanoplankton chlorophyll a concentrations (μg chl a l^{-1}); and whole-water (▲) and nanoplankton (♦) assimilation ratios (AR, μg C μg chl a^{-1} h^{-1}) for entrainment and nearfield stations in the vicinity of the C.P. Crane generating station, July 1979 through March 1980. The number beside each symbol represents the nanoplankton contribution as a percentage of the whole-water productivity or chlorophyll a concentration. In July, N-chl is nanoplankton chlorophyll; in July and August, N-P is nanoplankton productivity (from Ref. 12)


July
August
September
October
a
b
c
d
PI PD P2 P3 P4 P5 P6 P7 P8
μg CL⁻¹ h⁻¹
μg CL⁻¹h⁻¹; μg chl a L⁻¹; ARx10
chl (μg L⁻¹)
AR (μg C μg chl a h⁻¹)
N-chl
N-P


November
e
December
f
January
g
February
h
PI PD P2 P3 P4 P5 P6 P7 P8
µg C L⁻¹ h⁻¹; µg chl a L⁻¹
AR
µg C L⁻¹ h⁻¹; µg chl a L⁻¹; AR·10
µg C L⁻¹ h⁻¹; µg chl a L⁻¹; AR


March
μg C L⁻¹ h⁻¹
μg chl a L⁻¹, AR
0
2
4
6
8
10
12
0
5
10
15
20
25
30
P1
PD
P2
P3
P4
P5
P6
P7
P8
i
90
100
123
118
95
114
83
92

APPENDIX B.4 PHYTOPLANKTON STUDY

(Ecological Analysts, Inc.)

B.4.1 Objective

To determine the effect of plant operations on phytoplankton biomass, community structure, and productivity in the surrounding waters.

B.4.2 Data Sources

Refs. 3, 4, 5, 6, and 8.

B.4.3 Study History

Preliminary sampling was conducted from August to December 1978. This study was conducted from January to December 1979 as part of the comprehensive aquatic field studies done by Ecological Analysts for BG&E. The nearfield phytoplankton study was not extended into 1980 but was replaced with a phytoplankton entrainment study (Appendix B.6).

B.4.4 Methods

- Surface phytoplankton samples were collected at 7 stations (Fig. B.4-1) using a vacuum pump sampler. The intake hose of the sampler was held at a depth of 0.5 m and the boat was run along a transect of approximately 100 m while a 5-gallon sample was collected.

- Water samples taken approximately 0.5 m above the bottom were collected at each station using a 3-liter plastic Van Dorn bottle.

- Subsamples were preserved (1 percent Lugol's solution) at the time of collection for phytoplankton abundance estimates. Phytoplankton in each sample were identified to species when possible and were counted using a Palmer-Maloney nanoplankton chamber.

- Samples were filtered at the field laboratory for phytopigment (chlorophyll *a*) analyses. Chlorophyll concentration was measured by determining pre- and post-acidification fluorescence.

- ^{14}C uptake was used to determine productivity for surface water samples using a technique adapted from Strickland and Parsons (Ref. 30). All samples were incubated for 2-4 hours under available sunlight at the prevailing intake water temperature. Determinations of carbon uptake in the light were made in triplicate; one dark bottle control was included per station. After incubation, the samples were filtered and the filters were placed in scintillation vials with 20 ml of a premixed "cocktail" and returned to the laboratory for counting.

- Oxygen consumption rates were determined for whole-water samples taken 0.5 m above the bottom during May through October 1979. Incubation was initiated in the field in the dark at either intake or discharge temperatures, with three replicates at each temperature. Monitoring of oxygen decline was completed in the laboratory, in temperature-controlled incubators adjusted to the recorded conditions at the intake and discharge.

- Ancillary measurements at all stations included: light intensity in the air, at the sea surface, immediately beneath the surface, and at 1.0 m; temperature; pH; conductivity; dissolved oxygen at near-surface, mid-depth, and near-bottom; and surface alkalinity.

B.4.5 Analysis

- Taxonomic identification to species was conducted whenever possible and presented in rank-ordered species lists. Data were also presented as mean densities and relative abundances by the major algal division. ANOVAs were conducted on blue-green and diatom density data to test for station and seasonal differences. Selected treatment contrasts for individual stations were also conducted. Analysis of Covariance (ANCOVA) was performed on blue-green algae and diatom data using certain water quality parameters (temperature, salinity, and dissolved oxygen) as the covariates.

- Chlorophyll a, primary production, and assimilation rates were tabulated and presented. Comparisons of productivity among stations were made for each sampling date by ANOVA. Based on results of these ANOVAs, a Student-Newman-Keuls multiple comparison test was used to detect station differences. Assimilation numbers were tested for station differences by Friedman's rank sum test.

- The respiratory rate constant was determined for each station and treatment (intake or discharge temperature) according to the model:

$$DO_T = DO_I \cdot e^{-kT}$$

where

DO_T = dissolved oxygen at time T, mg l^{-1}

DO_I = initial dissolved oxygen, mg l^{-1}

$-k$ = rate constant for decline of dissolved oxygen in sample, hours^{-1}

T = time, hours

B.4.6 Results

- The taxonomic breakdown by algal division was: 3 blue-green (Cyanophytes) taxa; 36 greens (Chlorophytes); 2 nondiatomaceous Chrysophytes; 10 diatoms (Bacillariophytes); 1 dinoflagellate (Pyrrophyte); and 1 miscellaneous flagellate. The rank-ordered species list (Table B.4-1) shows that six taxa accounted for over 95% of the average density of all phytoplankton.

  Winter densities were very low for all groups; however, in spring, both diatoms and blue-greens developed large standing crops (Fig. B.4-2). The blue-greens persisted more than the diatoms in summer samples, but both groups remained well represented. In fall, blue-greens and diatoms still dominated, but at considerably reduced densities, and the small flagellates, collectively represented as "unidentified forms," became fairly abundant.

- Density and distributional trends indicated that blue-greens had a maximum density at Stations 6S (surface) and 6B (bottom) with secondary peaks at Stations 4S and 4B. Diatom density maxima occurred at Stations 5S and 5B. These patterns repeated themselves more or less consistently in all seasons except winter. In winter, total abundances were so low that, although peaks occurred, they were small when compared to the magnitude of the phytoplankton biomass during the remainder of the year.

- The ANOVA on blue-green algal distributions (all taxa added together) indicated significant seasonal density differences and a lack of significant station differences. However, when winter data were excluded from the ANOVA, significant seasonal and station differences were found. An ANCOVA found that removing effects of salinity and temperature eliminated the significant station effect, while removing effects of dissolved oxygen did not.

- A similar ANOVA to the above (without winter) conducted for diatom densities indicated significant seasonal and station effects. Treatment contrasts indicated that the discharge station (3) was significantly different from the others. ANCOVA, however, indicated nonsignificant station differences when the effects of each of the covariates (temperature, salinity, and DO) were removed.

- Chlorophyll a concentrations for 1979 are given in Table B.4-2. Consistent depth differences (surface and bottom) were not observed. Over the seasons of spring, summer, and fall, the stations considered to be influenced by the C.P. Crane power plant thermal effluent (3, 4, and 7) consistently ranked below Stations 5, 6, and 1 in standing crop (chlorophyll a). Statistically, however, no difference was demonstrated when the thermally influenced stations (3 and 4) were compared with the station nearest the intake (2), using a Friedman's rank sums procedure (s = 6.38, 9 degrees of freedom).

- Comparisons of potential productivity among stations were made for each collection by ANOVA. Significant differences among stations, at α= 0.05, were found for each sampling date. The results of Student-Newman-Keuls multiple comparisons are shown in Table B.4-3. Station 6, which through spring, summer, and fall generally ranked highest in chlorophyll a standing crops, generally exhibited higher potential production rates. No other consistent patterns among stations were observed.

- Although Station 3 (discharge) had consistently higher assimilation ratios, these spatial differences were not significantly different when Friedman's rank sum procedure was applied.

- Respiratory rate constants and the critical ratio, i.e., disappearance of oxygen, generally increased when water temperatures were increased from intake to prevailing discharge temperatures, there was no indication of oxygen depletion to stress-related levels. Differences among stations, although significant, did not reveal an obvious plant-related effect.

B.4.7 Significance and Critique of Findings

- Results generally are consistent with PPSP findings (Appendices B.1 through B.3) and suggest a limited localized effect on productivity. No evidence of plant impact in waters beyond the immediate discharge area was found.

- Results comparing surface to bottom differences may not be equally representative of respective measured parameters due to differences in sampling methodology; surface composite samples tend to integrate density differences across patches whereas bottom Van Dorn bottle grab samples do not.

- The ANOVAs conducted on blue-green and diatom abundances provided only limited information, since species data were lumped into groups and ANOVAs conducted on total densities. Hence, effects on community structure were not addressed.

Table B.4-1. Rank-ordered species list of all phytoplankton seen during the 1979 sampling in the vicinity of the C.P. Crane power plant (from Ref. 4)

SPP. NAME	NUMBER	%	CUMU. %
CYANOPHYTA TRICHOME	8414.	41.152	41.152
MICROSIPHONIA POTAMOS*	4778.	23.368	64.520
MISC. FLAGELLATES	2019.	9.877	74.397
MISC. PENNATE DIATOMS	1808.	8.844	83.241
MISC. CENTRIC DIATOMS	1634.	7.994	91.235
ANKISTRODESMUS FALCATUS	910.	4.452	95.686
AGMENELLUM QUADRUPLICATU	246.	1.205	96.891
MELOSIRA GRANULATA	140.	0.684	97.575
SCENEDESMUS QUADRICAUDA	123.	0.601	98.177
UNID. DINOFLAGELLATES	100.	0.488	98.664
ASTERIONELLA FORMOSA	46.	0.223	98.888
SCENEDESMUS ABUNDANS	36.	0.175	99.062
SCENEDESMUS DIMORPHUS	33.	0.162	99.224
TETRASTRUM HETEROCANTHUM	24.	0.120	99.344
WESTELLA BOTRYOIDES	22.	0.107	99.451
NITZSCHIA CLOSTERIUM	14.	0.070	99.521
SCHROEDERIA SETIGERA	12.	0.058	99.580
SCENEDESMUS DENTICU. V R	10.	0.049	99.629
CRUCIGENIA TETRAPEDIA	10.	0.047	99.676
TETRAEDRON CAUDATUM	9.	0.042	99.718
CLOSTERIDIUM LUNULA	9.	0.042	99.759
POLYEDRIOPSIS SPINULOSA	7.	0.034	99.794
PEDIASTRUM TETRAS	4.	0.020	99.814
SELENASTRUM GRACILE	4.	0.019	99.833
SKELETONEMA COSTATUM	4.	0.019	99.853
FRANCEIA TUBERCULATA	4.	0.017	99.870
SCENEDESMUS OBLIQUUS	3.	0.015	99.885
COSMARIUM SPP	3.	0.014	99.900
CHAETOCEROS SPP	2.	0.012	99.912
SCENEDESMUS BIJUGA V AL.	2.	0.012	99.923
STAURASTRUM SPP.	2.	0.010	99.933
CLOSTERIUM SPP	2.	0.009	99.942
DINOBRYON SP.	2.	0.009	99.951
SPONDYLOSIUM SPP	2.	0.008	99.959
GOLENKINIA RADIATA	1.	0.006	99.965
PEDIASTRUM BIRADIATUM	1.	0.005	99.969
CYANOPHYTA COLONY	1.	0.004	99.974
CLOSTERIOPSIS LONGISSIMA	1.	0.004	99.977
PEDIASTRUM DUPLEX V. GRA	1.	0.004	99.981
EUASTRUM SPP	1.	0.003	99.985
PEDIASTRUM DUPLEX	1.	0.003	99.988
SIGMOID DIATOM(GYR/PLEU)	1.	0.003	99.991
PEDIASTRUM TETRAS V. TET	0.	0.002	99.993
MELOSIRA GRANULATA V. AN	0.	0.002	99.995
ACTINASTRUM HANTZSCHII	0.	0.002	99.996
SYNURA SPP.	0.	0.001	99.997
CLOSTERIUM MONILIFORME	0.	0.001	99.998
SCENEDESMUS SPP.	0.	0.001	99.998
STAURASTRUM PARADOXUM	0.	0.001	99.999
EDELASTRUM SPP	0.	0.000	99.999
PEDIASTRUM SIMPLEX	0.	0.000	100.000
PEDIASTRUM SPP	0.	0.000	100.000

* *Skeletonema potamos*

Table B.4-2. Chlorophyll-a concentrations (mg m^{-3}) near the C.P. Crane power plant (from Ref. 4)

Month		Station 1	2	3	4	5	6	7
Jan	Surface	1.6	2.5	1.1	5.8	4.1	0.7	3.4
	Bottom	0.7	2.3	1.5	4.3	1.5	0.8	3.3
Feb	Surface	0.9	1.1	1.9	1.7	1.1	1.1	1.2
	Bottom	0.9	1.0	1.6	1.9	1.0	0.9	23.4
Mar	Surface	7.4	8.1	18.7	21.4	13.6	37.5	21.4
	Bottom	6.2	12.5	17.7	19.9	14.0	39.9	17.9
Apr	Surface	63.3	52.9	36.1	30.8	70.3	65.4	12.4
	Bottom	54.5	50.6	45.2	34.3	79.7	62.3	11.5
May	Surface	12.8	8.3	16.1	25.3	20.9	29.2	19.0
	Bottom	10.5	6.4	17.5	24.0	17.5	34.0	14.0
June	Surface	46.9	29.8	33.7	22.4	56.7	25.3	11.3
	Bottom	24.0	48.8	33.7	23.4	30.5	22.7	10.4
July	Surface	41.9	32.4	30.8	32.4	38.0	47.1	22.4
	Bottom	16.0	28.0	25.6	31.3	36.7	41.9	22.4
Aug	Surface	43.5	16.4	29.1	30.9	34.0	44.5	31.9
	Bottom	41.9	12.9	31.4	15.8	35.3	49.7	12.3
Sept	Surface	13.9	26.7	13.1	8.4	22.8	8.4	22.0
	Bottom	12.1	8.7	22.0	11.4	29.5	9.7	24.4
Oct	Surface	14.7	22.1	15.7	22.1	32.6	39.6	18.2
	Bottom	14.6	21.0	10.6	22.3	27.6	34.8	24.3
Nov	Surface	12.8	11.2	11.8	16.7	12.3	19.2	12.3
	Bottom	12.8	11.5	15.2	20.4	15.7	19.7	16.4

Table B.4-3. Multiple comparisons tests (Student-Newman-Keuls) indicating spatial differences in primary productivity near the C.P. Crane power plant, 1979. (Station means that are not significantly different are underscored.) (From Ref. 4)

Sampling Date	Station (increasing mean production rate) →						
9 JAN	DA6	DA1	DA2	DA3	DA5	DA7	DA4
7 MAR	DA2	DA6	DA7	DA5	DA4 =	DA1	DA3
4 APR	DA2	DA5	DA1	DA4	DA7	DA6	DA3
8 MAY	DA7	DA4	DA3	DA1	DA2	DA5	DA6
12 JUN	DA2	DA1	DA5	DA3	DA7	DA6	DA4
10 JUL	DA7	DA4	DA2	DA6	DA3	DA1	DA5
14 AUG	DA7	DA1	DA4	DA2	DA3	DA5	DA6
20 SEP	DA7	DA3	DA2	DA1	DA4	DA5	DA6
16 OCT	DA6	DA4	DA3	DA1	DA5	DA7	DA2
13 NOV	DA1	DA7	DA3	DA2	DA5	DA4	DA6
6 DEC	DA1	DA7	DA2	DA5	DA3	DA4	DA6

Note: α = 0.05.

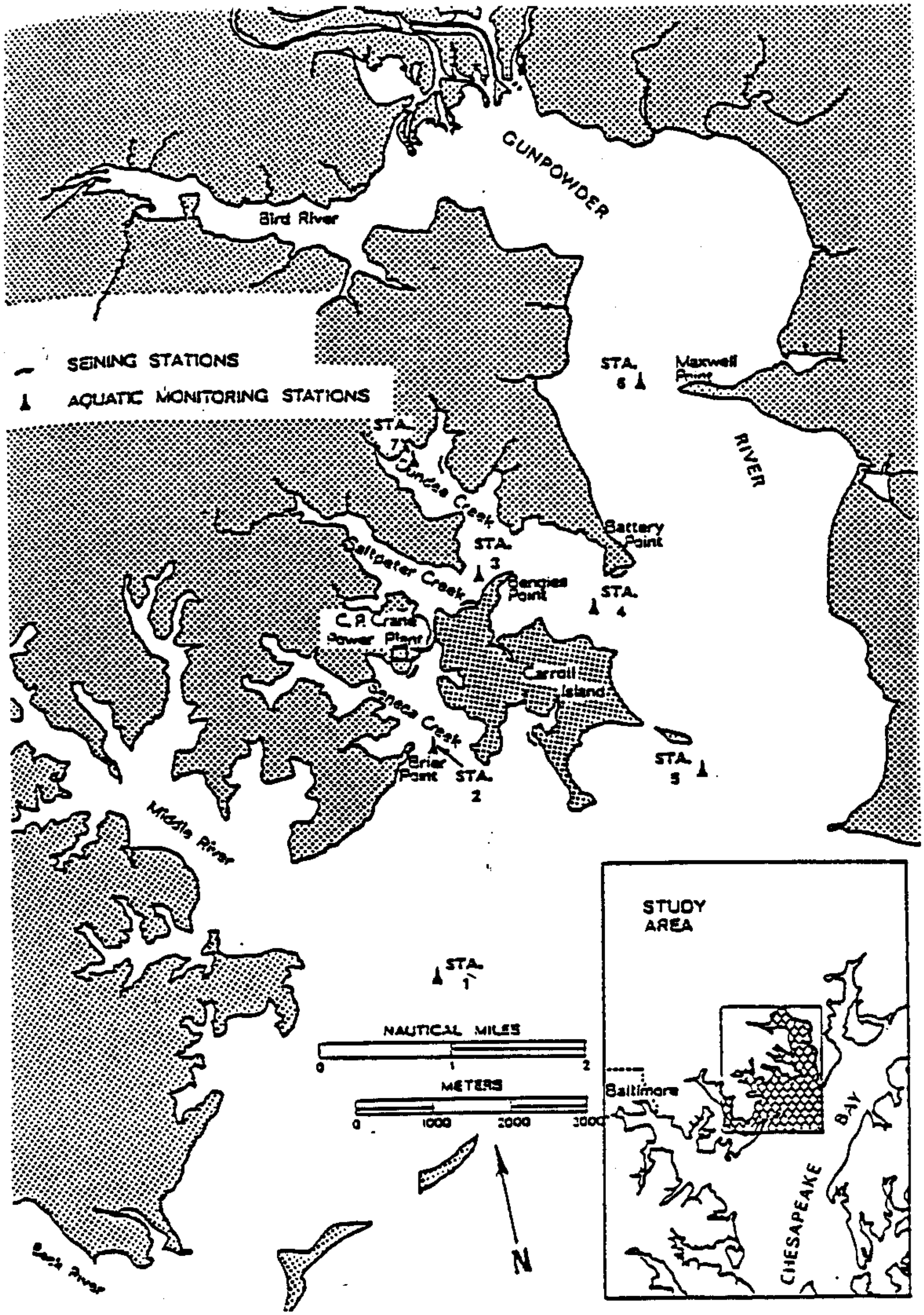


Figure B.4-1. Sampling stations near the C.P. Crane power plant (from Ref. 5)

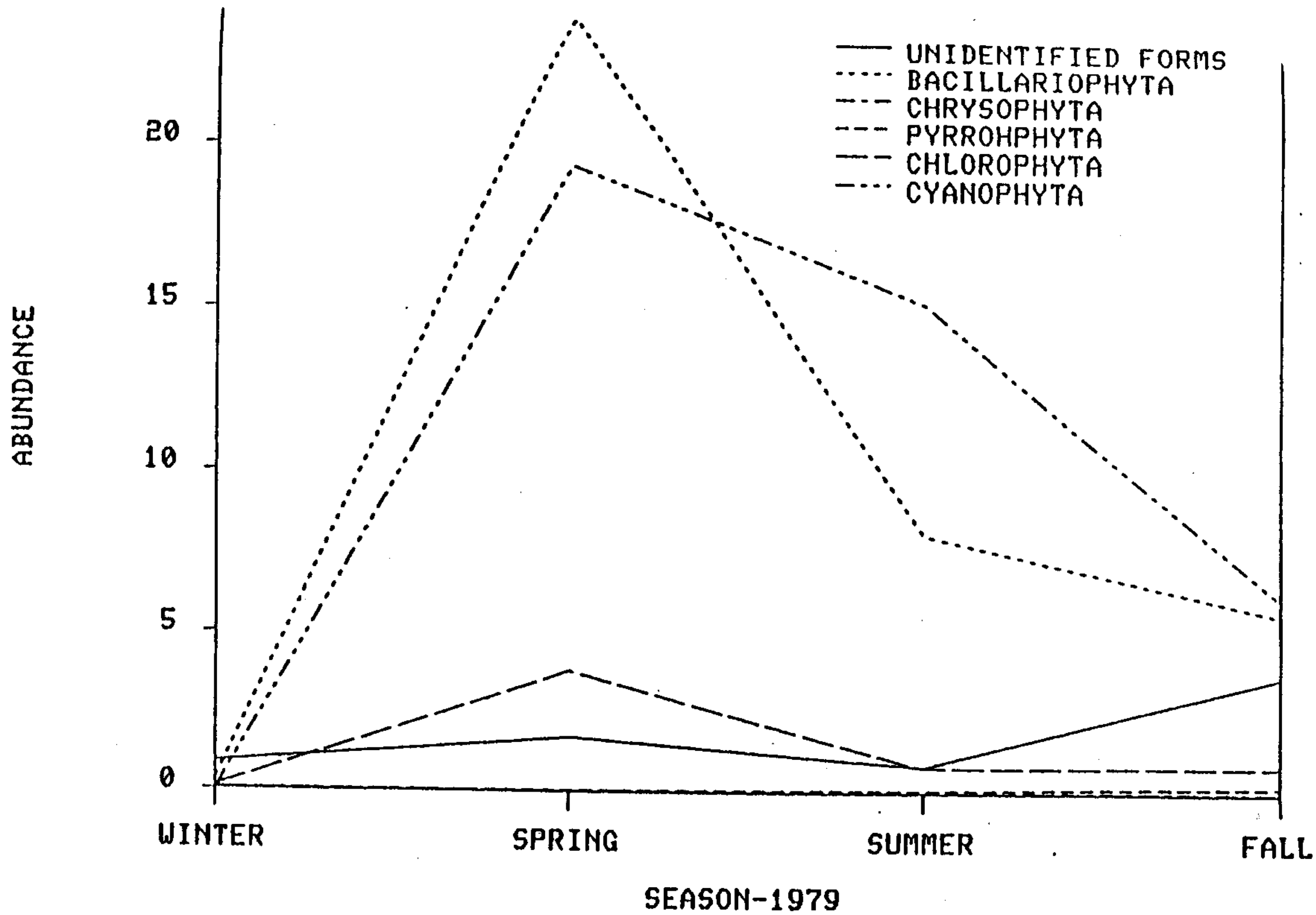


Figure B.4-2. Seasonal comparison of phytoplankton abundance (cells/ml) in the waters surrounding Carroll Island and the C.P. Crane power plant, 1979 (from Ref. 4)

APPENDIX B.5. OXYGEN METABOLISM

(P.L. Zubkoff, Virginia Institute of Marine Science)

B.5.1 Objective

A preliminary study to identify the factors that contribute to the net balance of community metabolism in the water around the plant and to determine the effect of plant operation on these factors.

B.5.2 Data Source

Ref. 13.

B.5.3 Study History

September, October, and December 1979.

B.5.4 Study Methods

- Sampling was conducted by two separate field crews, one in Seneca Creek and one in Saltpeter Creek. Sampling stations are shown in Fig. B.5-1.

- Physical and meteorological measurements recorded were sky (amount of cloud cover); sea state (extent of wave action); tide height (depth of probe); insolation; wind direction; wind speed; subsurface light penetration (secchi); surface water temperature; salinity; dissolved oxygen; and amount of suspended solids.

- Chlorophyll _a_ was measured to estimate standing crop (biomass).

- Productivity was determined by the oxygen dark-light bottle technique. Three-hour, half-day, and full-day incubations were done.

- Oxygen demand rates were determined from incubated samples.

B.5.5 Analysis

- Regression analysis was used to determine the rate of oxygen utilization per unit time ($mg\ O_2\ l^{-1}\ h^{-1}$).

- Dissolved oxygen, productivity, chlorophyll a, and physical measurements were plotted versus time and analyzed in relation to tidal stage and insolation.

B.5.6 Results

- The project experienced problems during each of the three sampling periods, due to plant shutdown and extreme meteorological conditions.

  -- September's sampling was terminated after 8 hours due to Hurricane David. The sampling period was too short to provide any useful information.

  -- October's sampling was conducted during a plant shutdown, providing a control test period.

  -- December's sampling was conducted following a period of high winds which caused lower than normal water levels. Stations P1, P2, and P3 in the discharge area could not be reached.

October

- October's community metabolism study provided an opportunity to compare intake and discharge sides of the power plant when there was little to no industrial heat output. Dissolved oxygen measurements on the discharge side of the plant were greater than those on the intake side whereas productivity appeared almost identical on both sides.

- Chlorophyll a (biomass) measurements at Gunpowder River stations during the October control sampling period were noticeably higher than chlorophyll a measurements in either Seneca or Saltpeter Creek.

December

- Phytoplankton standing crop (chlorophyll a) was higher ($10-15\ g\ l^{-1}$) in the discharge area then in the intake ($6-10\ g\ l^{-1}$).

- Dissolved oxygen values were always above saturation for the intake waters and near saturation for the discharge waters during the period of insolation. During the periods of darkness, dissolved oxygen values were below saturation in the discharge waters.

- Productivity at Station P04 (discharge) was seven times greater than at the intake.

B.5.7 Significance and Critique of Findings

- Due to extenuating problems, only two incomplete sampling sets were obtained: one during a plant shutdown and the other during a period of unusually low water levels. Insufficient seasonal data on community oxygen metabolism during plant operation prohibits making any overall evaluation of the plant's effect on the metabolism of the local environment from this study.

- Results suggest that dissolved oxygen concentrations are not depleted in discharge waters. This is consistent with findings from physical/chemical studies.

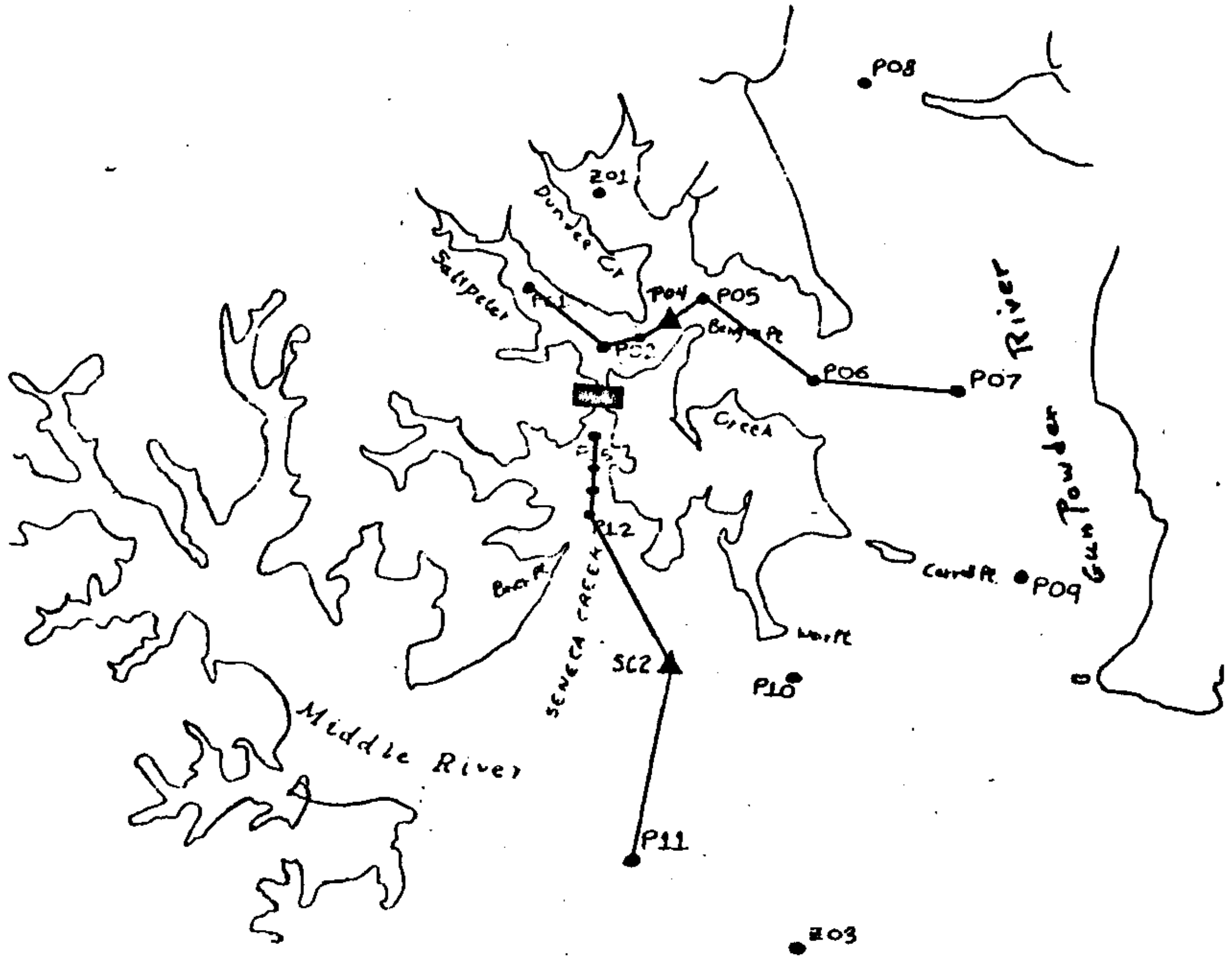


Figure B.5-1. Study area showing Seneca Creek, Dundee-Saltpeter Creeks, and Gunpowder River (from Ref. 13)

Intake: Seneca Creek -
Array Stations: P11, SC2, P12, P15
Anchor Station: SC2 ▲

Outfall: Saltpeter Creek - Gunpowder River
Array Stations: P1, P2, P3, P4, P5, P6, P7
Anchor Station: P4 ▲

APPENDIX B.6. PHYTOPLANKTON ENTRAINMENT

(Ecological Analysts, Inc.)

B.6.1 Objective

To examine the effects of plant entrainment on phytoplankton productivity, biomass, and community structure in the vicinity of the C.P. Crane SES.

B.6.2 Data Source

Refs. 5, 6, and 8.

B.6.3 Study History

This study ran from January through November 1980 and was part of comprehensive aquatic field studies conducted by Ecological Analysts.

B.6.4 Methods

- Sampling was conducted monthly for the productivity recovery assessment. Phytoplankton abundance was estimated monthly from January through March and weekly thereafter.

- Three replicate, whole water samples were collected at the plant's intake and discharge canal on each sampling date. Each replicate consisted of a composite of several 3-liter Van Dorn bottle casts taken at 1-meter intervals from the surface to the bottom at the intake, and from the surface, mid-water, and bottom in the discharge canal.

- One liter from each sample was fixed with Lugol's solution for taxonomic evaluation. The remainder of the sample was used for determination of ash-free dry weights, chlorophyll a and particulate organic carbon (POC) concentrations, and primary production.

- Primary production was established by ^{14}C uptake. Two light bottles and one dark bottle from each replicate sample were incubated in continuous-flow incubators at a depth of 2.5 cm under natural light. The experimental design included the following treatments:

TREATMENT	INTAKE	DISCHARGE
t + 0	Intake sample at intake temperature, followed by ^{14}C inoculation and ~ 2-hr incubation	Discharge sample at discharge temperature, followed by ^{14}C inoculation and ~ 2-hr incubation
t + 6	Intake sample held 6 hr at intake temperature, followed by ^{14}C inoculation and 2-hr incubation	Discharge sample held for 3 hr at discharge temperature and 3 hr at intake temperature, followed by ^{14}C inoculation and 2-hr incubation
t + 24	Intake samples held 24 hr at intake temperature, followed by ^{14}C inoculation and 2-hr incubation	Discharge samples held for 3 hr at discharge temperature and 21 hr at intake temperature, followed by ^{14}C inoculation and 2 hr incubation

- Phytoplankton samples were concentrated and abundances were determined by counting three replicate Palmer-Maloney nanoplankton chambers. Unit counts were given to each unicell and coenobial colony sets.

- Chlorophyll a and phaeophytin were extracted in 90% acetone and determined fluorometrically. No chlorophyll a determinations were made from January through June 1980.

- POC content was measured directly using a total carbon analyzer. Ash-free dry weights were determined after ashing at 500C for an unspecified time.

- ^{14}C activity was determined using a liquid scintillation counting technique. Counting efficiency was determined using the channels-ratio method and counts were corrected to disintegrations/ minute (DPM).

B.6.5 Analysis

- Average percent composition of the phytoplankton community and number of algal units/ml of major algal divisions observed in 1979 and 1980 were compared graphically.